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E. R.

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October 22	Vehicles	61 B.V.D., Georgetown, and 62 B.V.D., Irvine. (Sale at Central Halls, Glasgow.)	DIXON & WALLACE, LTD. (Dept. L), Bank Buildings, Graham St., Glasgow, E.1. (Tel. Bridgeton 2447.)
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THE ENGINEER

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TROUBLES IN HEAVY-OIL ENGINE OPERATION

In the latest "Report on Heavy-Oil Engine Working Costs," recently issued by the Diesel Engineers and Users Association, the word "performance" is included in the title and the following sentences are found in the introductory remarks made by the chairman of the Working Costs Committee :—"With regard to the item 'Troubles Experienced,' it is hoped that this will become a really successful part of the report. It is indeed the feature which recently caused us to add the word 'performance' to the title of the report, and it is hoped that members will take note of these 'troubles experienced' ; comment on them, and make them the principal feature of discussion. The very object of our Association is to bring to general notice troubles experienced by our members at home and abroad, to discuss the ways and means of avoiding such troubles and to see that designers and builders of heavy-oil engines are apprised of our views on these matters." The Association is to be congratulated not only on having such an entirely practical outlook but on putting it forward in such plain English. Indeed, the prominence given to "troubles experienced" as a major factor in the assessment of performance seems to us to sound a note which should reverberate wherever heavy-oil engines are made or used.

Perusal of the report and of the discussion thereon affords strong confirmation of the value of recording troubles experienced and most helpful must be the information thus provided, particularly when—as is the case in numerous notes and comments—it has been possible to report not only the trouble experienced, but the success attained in its removal or amelioration. The communications from engine users cover a wide range of troubles including piston fractures, liner wear, cracked cylinder heads, water leakage into crankcases, spring breakages, connecting-rod bottom end bearing failures, sticking of piston rings, wastage by corrosion and sticking of exhaust valves. Since the report includes information as to the type and size of engine, nature of service, plant hours run, units generated, load factors and other significant operational details, it is in some cases easy to note the influence of operating conditions, as, for example, where it is stated (in connection with a waterworks engine) that "the low rate of wear of its liners (0·0003in per 1000 hours) is attributed to continuous operation under close automatic temperature control." This gives authentic confirmation from good practice of the general experience that a definite relationship exists (other things being equal) between cylinder liner wear and the hours run per engine start. In an instance where excessive cylinder liner wear (0·02in per 1000 hours) is reported, the close proximity of a stone-crushing plant is mentioned as the cause. Persistent valve spring breakages are shown to have been arrested by the use of new springs coiled from ground wire. Where failure of connecting-rod bottom end bearings has been previously reported, the trouble has ceased "largely because of the close attention paid to the keeping of minimum clearances consistent with cool running." Interesting figures are given in illustration of the saving achieved by the utilisation of heat otherwise wasted. In one example the saving shown is equivalent to a reduction of the total cost of power generation from 1·407d. to 1·097d. per unit generated and the discussion contains information and suggestions which are of special significance in connection with the economics of waste heat recovery.

The attentive reader of this report and of the discussion which followed its presentation, cannot fail to appreciate the service performed by the Diesel Engineers and Users Association in making available information derived from actual installations. We note that the returns published this year include the working costs and performances of internal combustion engine plant at forty-nine electrical generating stations in Britain, thirty-three generating stations overseas, and nineteen British water pumping stations, a total of 101 stations. To collect, classify, and analyse the data on which the report is based and to present it for the information and guidance of engine users, engine manufacturers and the suppliers of fuel and lubricating oil, is to perform a national service. It is to be hoped that the labour expended in the production of this report will fructify in the promotion of wider knowledge of the subject dealt with and in advancing the use of procedures likely to effect economy in operation and reduction in maintenance cost. We cannot doubt that the publication of such a report provides a powerful incentive to co-operation on the part of companies supplying fuel and lubricating oil and of manufacturers of engine components and accessories. Finally, there is about the report and discussion something which

must convince the reader that its value lies not only in the accumulation of data, but (to quote words used three and a half centuries ago by Lord Bacon) in "a wisdom won by observation," for, as the same great apostle of science has remarked: "Studies themselves do give forth directions too much at large, except they be bounded in by experience."

INSTITUTION MEETINGS

The increase in recent weeks, in the amount of space required for our announcements of "Forthcoming Engagements" is a forceful reminder that another season of institution meetings is upon us. Over the next seven or eight months, scores of presidential addresses and special lectures will be delivered and several hundred technical papers will be presented for discussion. The time and thought demanded for the preparation of all these addresses and papers are incalculable; the only reward for which many of the authors can hope is that their contributions add something worthwhile to the important business of diffusing technical information and opinion as widely as possible. We have no doubt about the value of the great majority of the lectures and papers published by the numerous engineering institutions and societies now in being. Nor have we any doubt about the value of the verbal exposition and discussion of technical problems. We naturally support the tenet that "reading maketh a full man," but we acknowledge just as freely that conference makes "a ready man."

What, however, does make us a little uneasy is the pattern of many of the meetings of technical institutions and societies. There are some at which the author is called upon to read his paper *in extenso*, while those present turn over the pages of the advance copies handed to them as they arrive; there are others at which a lengthy summary is substituted for the reading of the full text. When the time for discussion ultimately is reached, it is by no means unusual for those who have been previously invited to set the ball rolling to produce longish scripts which they read to the assembled company. Such contributions, valuable though they may be, all too often have the flavour of another paper. So tedious, in fact, can the proceedings become that members of the audience are glad to slip away as unobtrusively as possible to catch trains, the actual departure times of which they have been trying to remember for the preceding half-hour! If technical meetings were rather less formal than they now tend to become, a livelier interest in their proceedings might well be maintained. Furthermore, we believe, there would be less reluctance to participate in discussion. The art of public speaking is one that is not easily mastered even by the most knowledgeable people; but there are many such people who can usefully join in something rather more conversational. We do not overlook that a few institutions still include informal meetings in their programmes, but the trend of the majority appears to be away from the informal meeting. So much so, in fact, that we cannot resist the temptation to recall that, in a day now past, members of several technical societies met in coffee rooms or taverns for serious discussion. The contents of mug or tankard may have been conducive to an atmosphere of conviviality, but there must have been many a discussion or conversation, in such an atmosphere, that has assisted the progress of engineering and other technologies!

SEVEN PER CENT

The increase in the Bank Rate to 7 per cent announced on Thursday of last week could not have much immediate effect in stemming the international flight from sterling. For to a speculator the change of rate of interest was negligible relative to the profit or loss to be made were the pound sterling to be devalued. Thus it is only now, a week later—the pound sterling having survived pressure which was more probably increased rather than reduced by the announcement—that the pressure shows signs of easing. The raising of the interest rate had, we believe, a longer term object; for it is notable that its announcement was accompanied by a governmental statement that the total investment expenditure in the public sector would not be allowed to rise as planned but would be held to this year's level. In fact, inflation is to be halted by holding down the capital expenditure of the country in the hope, presumably, that a greater proportion of the total national output will be made available to meet the inflated demand for consumption goods. But as engineers, aware by how much productivity can be raised by the application of new machinery and new plant, we can hardly be expected to greet with any enthusiasm a plan of action based upon the idea that the rate of production of such machinery and plant should be held back! Nor do we believe it to be in the longer term national interest that capital expenditure should be reduced.

In regulating a nation's finances a Government needs to bear in mind that the whole national output is divided between the production of goods for immediate consumption, goods for export and capital goods. Expenditure on capital goods, because it tends to increase the national output, should, it is abundantly clear, be maintained at as high a level as possible. Why, then, is it that the Government is placing a check on the production of these capital goods? To find the answer it is necessary to examine by what means the Government can control the division of the national output. The Government has, in fact, little or no control of the demand for consumption goods; for this demand is largely fixed by wage rates. If wages rise more rapidly than productivity there are, therefore, four principal courses open to a Government. First it can take no action. It will follow that to meet the increased demand for consumption goods imports will increase in volume and goods will be diverted from export to the home market. In short, there will be a balance of payments crisis. Secondly, it can do what the Conservative Government is doing; that is it can put a check on the production of capital goods, thereby causing a greater proportion of total output to be devoted to consumption goods. Inevitably the consequence is that the rate of increase in productivity falls and the standard of living fails to rise. Unemployment may be caused. If pursued too far this policy leads to economic stagnation, if not to economic disaster. Thirdly, a Government can act directly against consumption by raising direct taxation, by increasing purchase taxes, by making hire purchase more difficult and, if prepared to accept counter-action by other nations, by imposing import duties so as to raise the price of imported goods. Unfortunately, the consequence proves to be immediate demands by unions for higher wages, thus restoring the *status quo*! Lastly, a Government can act as it acts in war; that is it can clap on controls, regulating the capital expenditure of companies and even reverting to rationing of retail goods if necessary. This appears to be the socialistic answer. But as it amounts to a claim that the Government should decide what individuals ought to want to buy it seems to us a direct attack on the freedom of an individual to buy, within the limits of his income, whatever he chooses. It would be deplorable if the country was driven to accept that expedient.

In looking at the practices of the two major political parties under these circumstances we are inclined to cry "A plague o' both your houses!" For neither dares to attack the real cause of this country's economic ills. The trades unions may vehemently claim that wage rates are a private matter for them to negotiate with employers. But is this a claim that can nowadays be conceded? For our part we do not think so. It is, indeed, obvious to us that the nation has a great and very direct interest in the outcome of these negotiations. The Government has the means directly and indirectly to regulate the expenditure of industry on capital account. Lacking, however, the means to limit wage increases, it cannot control the country's economy. Governmental policy, in short, can be brought to nought by the actions of trade union leaders.

A Seven Day Journal

British Electricity Supply 1948–57

THE ninth annual report of the Central Electricity Authority which was published earlier this week will be the last of its kind to be issued by the present régime. For the functions of the Central Electricity Authority will be taken over, as from January 1, by two new bodies, the Electricity Council and the Central Electricity Generating Board. It was appropriate, therefore, that, at his recent Press Conference, Lord Citrine, the chairman of the C.E.A., should review some of the changes in the electricity supply industry in the nine years that it has been co-ordinated under the Authority. The present generating capacity of 20,644MW is double that of 1948 and the capacity is expected to be about 36,000MW by 1965. Contracts have been placed for three nuclear power stations with a total generating capacity of 1100MW ; two of them are due to be in operation by 1960/61 and the third by 1962. A suitable site for a fourth station has been determined.

Whereas most of the generating sets on order in 1947/48 were 30MW or 60MW sizes, sets of 100MW and 120MW are now coming into service, while sets of 200MW are on order and others of 275MW, with appropriately higher steam conditions, are in the design stage. For the next stage of development a 550MW set comprising two 275MW sets, cross-compounded, is on the drawing-board. Corresponding rises in generating efficiency are attainable—37 per cent for the 200MW sets and slightly more for the larger machines, compared with 27·4 per cent for the 30MW sets. Consequent reductions in the physical size of station buildings spring from the fact that the larger present-day plant requires about 35 cubic feet per kilowatt, compared with about 40 to 60 cubic feet per kilowatt in 1948. Thus, despite increases in costs, the present cost of a station per kilowatt is no higher than it was in 1948.

The average price of electricity to-day is 28 per cent above that of 1948 and 38 per cent above the pre-war price. Allowing for the effect of inflation, electricity is, therefore, cheaper in terms of real value than it was before the war. In each year since vesting day the supply industry has made an overall surplus, ranging from £3,600,000 to £18,500,000, and the aggregate surplus over the nine-year period is about £82,460,000. In the year ended March 31 last, the aggregate surplus, taking the combined results of the Central Electricity Authority and the Area Boards, was £11,718,915.

Development of the Weaver Navigation

BRITISH TRANSPORT WATERWAYS has announced improvements costing over £260,000 on the Weaver Navigation, in the North Western Division. This proposal is part of the British Transport Commission's £5,500,000 development plan for the principal inland waterways, and is designed to enable this short, but important, water route to cater for the increasing use of seagoing vessels. Well over 500,000 tons of traffic a year is carried on the Weaver Navigation, which comprises the Weston Canal and the River Weaver, and which links the industrial centres of Winsford and Northwich with the Manchester Ship Canal and the River Mersey. The programme includes bank protection and navigation works costing £126,800 ; mechanisation of locks and sluice improvements, costing £33,100 ; new dredging plant, costing £64,000, and improvement of workshops and other premises at a cost of £36,900.

The worst of the bends on the waterway, which follows the course of the River Weaver, have already been improved, but a number of the remaining bends are to be realigned. A diversionary channel is to be constructed to avoid the disused Sutton Locks. In the Weston Canal a triangular piece of land adjacent to the waterway, between Marsh Lock and Weston Point, is to be dredged out to form a turning area for vessels. The locks at Dutton and Saltersford are to be mechanised to enable the lock gates and sluices to be operated simultaneously from a central point.

The Engineer
100 Years Ago

(SEPTEMBER 25, 1857)

"RAILWAY REPORT FOR 1856"

"The proceedings of the railway department for the past year have just been issued in the usual form of a report from Captain Galton to the Lords of the Committee of Privy Council for Trade and Foreign Plantations. The report contains a vast body of railway statistics for the year, showing all that was done as well as that which was not done, and making a guess, which we believe is a pretty good one, of that which never will be done. . . . . The total length of railway authorised by Parliament to the end of last year was 14,668 miles ; but of this 1,495 miles have been *authorised* to be abandoned, leaving 13,163 miles made and to be made. Now, although it is generally believed that as a person has made his bed so he must lie on it, it has not, we are sure, been generally understood that any number of gentlemen, having spent half their fortunes getting a railway bill through Parliament, are obliged to obtain leave not to spend the other half in constructing the line itself.

"To the end of 1856 there were 8,635 miles of railway opened for traffic, which left 4,538 miles to be opened at that time ; Captain Galton thinks, however, that 2,532 or more than half of this number of miles of railway will never be made, although it does not appear that the promoters have been authorised to leave them alone. . . . With regard to the traffic, the total number of passengers conveyed on the railways in 1856 was about 129½ millions against 118½ millions in 1855, the number conveyed per mile being 15,213 in 1856 against 14,503 in 1855. . . . The total revenue from all sources for the United Kingdom in 1856 was about 23 millions sterling or £2,724 per mile, against 21½ millions or £2,629 per mile in 1855, showing an increase of more than 3½ per cent. Another interesting part of the report relates to the working expenses of railways for 1856. The proportion which they bore to the receipts was 49 per cent in England and Wales, compared with 48 per cent in 1855."

London-Yorkshire Motorway

THE Ministry of Transport and Civil Aviation has announced that within the next few weeks tenders will be invited for the construction of the first 53 miles of the London-Yorkshire motorway, from a point just south of Luton to Dunchurch, near Rugby. There will be four contracts, each for a length of between 12 and 16 miles, and work under each contract is scheduled to start next March. Contractors will be invited to submit alternative tenders for completion by either October, 1959, or October, 1960. At the same time the Hertfordshire County Council will invite tenders for building the St. Albans by-pass which will link with the southern end of the motorway and will be over 16 miles long and built to motorway standards.

In each of the four contract lengths of the London-Yorkshire motorway it will be necessary to excavate about 2,500,000 cubic yards and surface about 600,000 square yards. Altogether there will be six two-level junctions, forty-six bridges over public roads, eight railway bridges, three canal bridges, five river bridges and many smaller bridges. The consulting engineers for the scheme are Sir Owen Williams and Partners.

Work on the St. Albans by-pass is scheduled to start and finish at about the same time as work on the first section of the motorway. The line of the proposed road begins at a point on the North Orbital Road (A.405) south of St. Albans, and ends on the London-Glasgow Trunk Road, A.6, at Kidney Wood, Luton. Near this point it joins the London-Yorkshire motorway. There will also be a branch to the Watford by-pass, A.41. There will be seven junctions on the by-pass. Four of them, including that with the motorway, will be flyovers ; the others will be surface roundabouts, to be built at the three terminal points. The scheme will include thirty-nine bridges to be constructed in reinforced concrete. Hertfordshire County Council is preparing the contracts, although some of the bridges are being designed by Sir Owen Williams and Partners.

Proposal for a Tower Block at Millbank

A PROPOSAL for an office block at Millbank which includes a tower block of thirty storeys (that is, nearly 350ft in height), has been given planning approval by the London County Council. The site is near the Tate Gallery, next to Thames House, and is now occupied by contractors' plant yards and houses ; it is 3½ acres in extent. The building is to be on Crown land, leased to the Legal and General Assurance Company, who will develop the scheme in association with Vickers, Ltd.; the Vickers group of companies will be the principal tenants when the scheme is complete.

It is characteristic of contemporary building schemes of this kind in central London that large areas of office space are needed, but at ground level open spaces are also a desideratum, for car parking as well as for the general improvement which they bring. The architectural solution favoured is a tower block flanked with an array of comparatively low buildings, arranged with generous courtyards and open areas. One such scheme—the "Shell" building on the South Bank—is already under construction, and we published an article on the special foundation problems of its design a few weeks ago. The Millbank scheme is characteristic of such development, in that the office area provided will be as great as 350,000 square feet, and the scheme also includes flats, gardens and car parks.

It is too early yet to give details of the structural and foundation problems of this scheme. We understand, however, that the structural frame for the building generally, including the tower, is to be of reinforced concrete ; some form of light cladding is also to be used. The architects are Messrs. Ronald Ward and Partners, the consulting engineers Messrs. Travers-Morgan and Partners, and the contractor John Mowlem and Co., Ltd., the present lessees of the site.

Problems of Combined Creep and Fatigue Design

By A. J. KENNEDY, B.Sc., Ph.D., A.M.I.E.E., F.Inst.P.*

Although the actual conditions which occur in practice in high temperature machines and in special structures, such as aircraft, may be very complex in their nature, technological development has been based almost entirely on standard tests under fairly fixed conditions. As a result, the fatigue or the creep properties of materials are examined in isolation, usually at constant stress and temperature. The more fundamental aspects of these processes have also been studied in isolation, and consequently few pointers have been provided for the development of a more realistic testing policy. The difficulties which arise in dealing with the generalised problem of the simultaneous operation of deformation and fatigue processes, under varying conditions, are so great that the established test methods, and the approximations they involve, may well be thought adequate for the purpose. The greater the demands that are made on materials, however, the less adequate such approximations will become. From an economic point of view, the present system is already too expensive to be capable, in its present form, of a general expansion, even if this were desirable on scientific grounds. The fact is that some changes must come in the future and exactly what form they will take depends upon the results of research. As yet these results are too insubstantial to offer more than an outline of what will be involved. It is useful, however, to take stock of the present situation and this article therefore reviews the evidence relating to interaction between the two processes of deformation and fatigue, particular attention being given to the case where the deformation occurs by creep.

THE problems which confront the designer in dealing with either simple creep or simple fatigue in structural assemblies have many features in common. In each case, the worst conditions, from the point of view of stress and temperature, have to be established, and the behaviour of the material determined under stress cycles of possibly complex wave-form. This determination involves the acceptance of some kind of cumulative law, however approximate this may be. In one case the law refers to the accumulation of strain and in the other to the accumulation of fatigue cycles and hence of fatigue damage. The problem is so to arrange matters that over some selected working period both the creep strain and the fatigue damage are kept within certain specified limits.

To deal with creep under complex conditions is difficult in itself. More information is required than that provided by standard creep tests alone, as an important consideration in the calculation is the rate at which the creep resistance, developed by the deformation, is dissipated by the recovery processes when the creep stress is reduced or removed. This rate is strongly temperature-dependent, in the same way as the creep rate itself, and no adequate computations can be made without taking into account the temperature cycles in the machine, the rates of heating and cooling, and so on. This problem has been specially discussed elsewhere.[1] Although such calculations may be difficult, and are still under development, it does at least seem possible that special methods of computation, coupled with a revised basic testing policy, may enable very good predictions to be made. A much more elusive question at the present time concerns on the one hand the validity of such considerations when fatigue stresses are present, and on the other, the validity of the fatigue design when deformation by creep is occurring.

The general need to take account of a stress system comprising both a static and an alternating component is well recognised, and a number of suggestions have been made for reducing this to design form. Usually a diagram is prepared with the axes representing the alternating stress σ_f and the steady stress σ_c (see Fig. 1). Curves may now be plotted on such a diagram to represent the required design limits. The end points are readily entered: the first is that for the acceptable fatigue stress under zero static stress (*A*) and the other that for acceptable deformation or creep under zero fatigue stress (*B*). The equation to the design line between *A* and *B* has received considerable discussion, straight lines, ellipses and various other forms all being proposed, the point *B* usually being the yield or the ultimate stress. Whatever its form may be, such a line gives the possible limiting stress conditions for some selected lifetime at a given temperature.

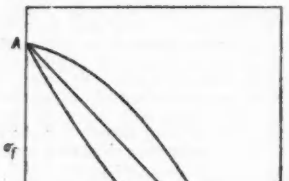

Fig. 1—Various forms of the limiting design line relating σ_f to σ_c

The fact that behaviour is really much more complicated than that represented by such a diagram, particularly when the loading cycles are complex, discontinuous and not at isothermal conditions, is generally accepted. The difficulty is to reduce the scattered and sometimes conflicting observations on the behaviour of particular materials to a form which lends itself to a design application. As a result of certain recent researches, some of these complicating effects are becoming better established, although it needs to be strongly emphasised that in all cases where any form of metallurgical transformation, such as recrystallisation, or precipitation, or ageing, occurs, quite different effects may arise.

Before examining these problems in particular detail, it may be useful to note certain special difficulties which arise in dealing with material behaviour under alternating stresses.

The first difficulty is simply that of measuring the amplitude and the wave-form of the stress in the test piece itself. Due to the different resonant frequencies of the individual components that make up the testing assembly, considerable errors can arise. The ideal solution is, of course, to use the test piece itself as the stress detector, but as this is nearly always impossible, the best that can be done is to record the dynamic stresses close to the test piece, preferably at the resonant frequency of the test piece itself. The actual detectors have resonances in themselves, however, and as soon as measurements are made at frequencies other than that of test piece resonance, more difficulties arise. Such a situation is familiar enough to those who have been concerned with dynamic stressing, but it is of vital importance where a frequency effect is being sought in fatigue. It is doubtful if very many of the frequency-effect investigations have given these questions the attention they deserve.

The second point regarding dynamic stressing has to do with the material itself. Even quite simple metallurgical materials are, of course, complex in their structure on the atomic scale, and a variety of different mechanisms can occur within them. Most of these mechanisms, or processes, can be characterised by a relaxation time, and the absorption of energy by any particular process depends upon the frequency of the applied stress. This is evidenced, of course, by damping behaviour, the amount of damping being a function of the temperature, for a fixed frequency, exhibiting peaks at certain temperatures, with maximum energy absorption. Temperature and frequency (and, thus, wave-form) are important factors in determining what occurs in metals under dynamic stressing, and all too little consideration has been given to them. The results which have been obtained on frequency effects are quite conflicting, as would be expected from the foregoing, for there is no reason to suppose that the fatigue response to frequency should not be both complex and particular to the metal under examination. At the same time, it is very possible that at fairly low frequencies and temperatures the fatigue response is less sensitive to these variables and as a consequence data collected in this region may have a reasonably wide application. This, however, has to be proved before general deductions may be made.

The Effect of Fatigue Stresses on Creep Deformation

In the absence of a fatigue stress, continuous creep can be described by laws which, from one point of view, may be regarded as laws of work-hardening. When the stresses are not constant, nor continuously applied, this work-hardening may be dissipated during the low-stress periods, by processes of recovery, and it is therefore true to say that an adequate extension of creep prediction to the case of discontinuous creep is possible only when these recovery laws are determined and expressed in a suitable analytical form. When fatigue stresses are present, both the processes of work-hardening in creep as well as the reverse processes of recovery are affected.

It has been known for some time that the application of a fatigue stress increases the creep rate, although certain evidence suggests that this becomes less significant as the temperature is increased, possibly resulting ultimately in a deceleration. Such observations have to be considered in the light of the discussion given above: the temperature change, as far as any process with a temperature-dependent relaxation time is concerned, is similar in its effect to a frequency change,

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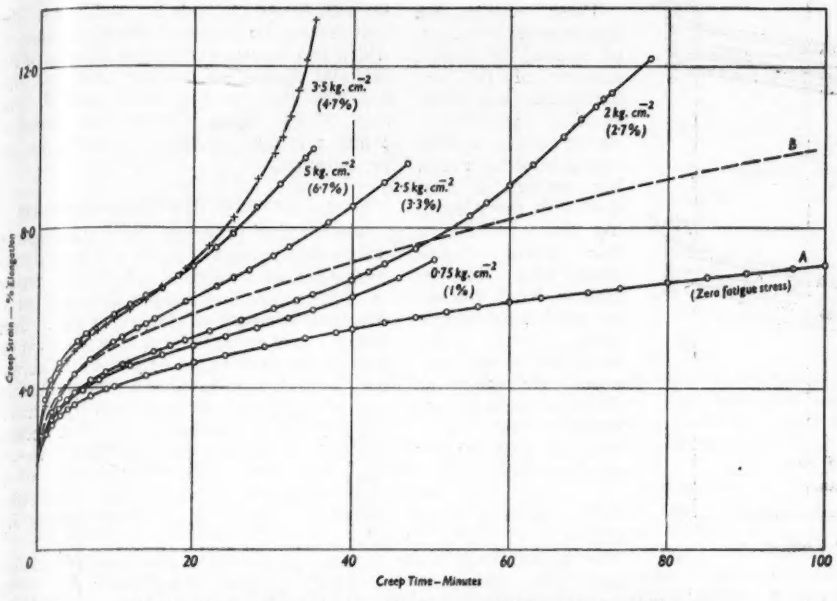


Fig. 2—Creep under various combined creep and fatigue stress conditions

and it depends entirely on the characteristics of the particular material how this in turn affects the distribution of absorbed energy. Anomalous results are to be expected when investigations are approached in this way.

The nature of the practical effects may be seen from Fig. 2, which shows how the creep of a low-melting point metal (lead) at about room temperature depends upon the value of the superimposed fatigue stress. The important point to bring out, as far as these results are concerned, is that a greater creep strain is achieved, in a given time, by a combined stress $\sigma_c = \sigma_0 + \sigma_f \sin \omega t$ than by a steady stress of $\sigma_0 + \sigma_f$, the peak value of σ_c.

In Fig. 2 the results are shown of tests at 32 deg. Cent. under a fixed static stress of 75 kg.cm^{-2} but with differing fatigue stresses (all at 300 c/s) superimposed. The purpose of including the dotted curve, which shows the creep under a static stress of 80 kg.cm^{-2} (i.e. a 5 kg.cm^{-2} increment) and zero fatigue stress, is to compare the effect of a static stress increment with an equal fatigue superposition. It will be evident that this curve lies below that for creep under a fatigue stress of 2·5 kg.cm^{-2} and that the life is much prolonged. The results show, in fact, that the addition of 5 kg.cm^{-2} of alternating stress reduces the creep life to about a third of that for the case where the 5 kg.cm^{-2} is added statically. Such an effect cannot, of course, be deduced from the standard set of static creep curves, and underlines the importance of this type of test in practice.

By applying the fatigue stress intermittently during the creep, more insight is offered into the way in which the fatigue is affecting the deformation. The results of such experiments are given in Fig. 3, showing the intermittent application of a fatigue stress, for periods of ten minutes, during the course of creep. The type of stress history is shown, without any quantitative scale, beneath the creep curves. The effect of adding a fatigue stress is superficially similar to that of simply increasing the static stress for a period, but differs importantly in detail.

A comparison with one such test (static increment, Fig. 3) may be made, and from such an examination two main differences emerge. First, while both static and fatigue increments cause a small transient to occur, the average creep rate during the incremental period is much greater in the case of fatigue, and is equivalent, as far as description is concerned, to a markedly increased steady-state creep. Secondly, when the increment is removed its effect in reducing the creep rate under the original stress is greater in the case of the static increment. Thus we find that although the fatigue increment results in greater strains, these strains are achieved with less work-hardening than that incurred by much smaller strains under wholly static loading. It is quite evident, then, that the processes of creep under the two conditions are significantly different in their nature as well as in their effects. The phenomena as a whole could be expressed by saying that the existence of the fatigue stress reduces the rate of work-hardening. The fact that the creep rate is increased may, in this sense, be a purely secondary effect, the primary one being the action of the fatigue stress on the recovery processes. This proposition may be tested directly.

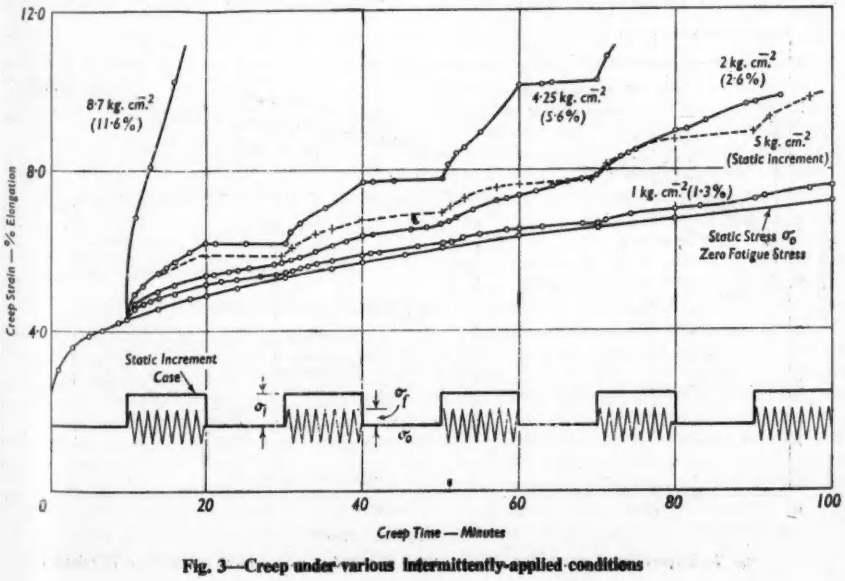

8·7 kg. cm.⁻² (11·6%)
4·25 kg. cm.⁻² (5·6%)
2 kg. cm.⁻² (2·6%)
5 kg. cm.⁻² (Static Increment)
1 kg. cm.⁻² (1·3%)
Static Stress σ₀ Zero Fatigue Stress
Static Increment Case
Creep Strain — % Elongation
Creep Time — Minutes

Fig. 3—Creep under various intermittently-applied conditions

If during the course of a constant-stress creep test the stress is removed for some selected period and then reapplied, the subsequent creep on reloading exhibits a transient due to a partial recovery of the original, fully annealed, transient creep properties. A fairly detailed study of these characteristics has been made elsewhere.

This basic experiment offers a means of examining directly the nature of the effects that fatigue stresses have on worked metals. For instance, if we adopt a standard set of conditions, varying only the duration or the amplitude of the fatigue stress, then we may use the creep behaviour to deduce a measure

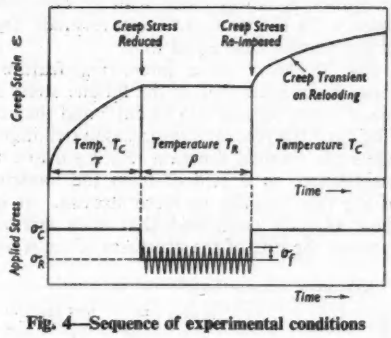


Fig. 4—Sequence of experimental conditions

of the recovery brought about. The programme for such a test is shown in Fig. 4, and the full experimental variables are :—

σ_c—The creep stress.
σ_R—The static stress during the " off-load " or recovery period.
T_c—The creep temperature.
T_R—The recovery temperature.
σ_f—The fatigue stress amplitude.
f—The fatigue stress frequency.
τ—The duration of the creep prior to the recovery period.
ρ—The duration of the recovery period.

In the tests to be reported, $T_c = T_R$ and is fixed throughout $\sigma_R = 0$, and both σ_c and f take fixed values. Three variables remain ; these are σ_f, τ and ρ.

It is convenient first to fix τ and vary only ρ and σ_f. A set of results obtained is shown in Fig. 5, and it will be seen that the effect of the fatigue stress is a function of both ρ and σ_f. In order to extract from these results some useful index of the measure of the fatigue effect, we express the observed transient on reloading as a fraction of the original creep transient for the metal. Thus, suppose the original transient creep to be given by an equation of the form $\epsilon = \beta_1 t^m$ where ϵ is creep-strain, t time, and β_1 and m constants. We find that the reloading transient may be given by $\beta_2 t^m$, and by taking $\beta_2/\beta_1 = n$, a fraction, we obtain a useful practical index of the amount of recovery, n

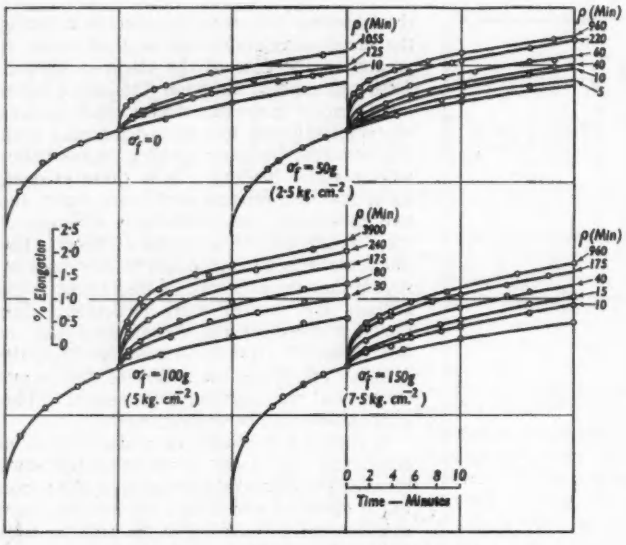


Fig. 5—Creep results for various values of ρ and σ_f

being equal to unity if the creep properties are fully restored, and equal to zero if no recovery at all has occurred. The values of n so derived may be plotted in the way shown in Fig. 6. The abscissa adopted in this figure is convenient, and no special significance need be attached to it here. The fact is that for cases of simple recovery ($\sigma_f=0$) the quantity n is closely linear with ρ^m, being the constant in the transient creep formula, and in the present case equal to $\frac{1}{3}$.

Fig. 6 shows some interesting features. First, it confirms that as the fatigue stress is raised from zero to 2·5 kg.cm^{-2} and then to 5 kg.cm^{-2} the recovery is increased strikingly, while the original function relating n to ρ is maintained, as is evident from the linearity of the relationships at these stresses. It is, then, directly confirmed that such stresses increase the rate of the processes of recovery,

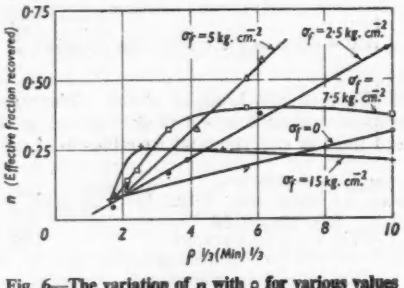


Fig. 6—The variation of n with ρ for various values of σ_f

and it is highly probable that in this range at least they do not alter their basic character. However, if the stress is increased further, the initial linear region reaches a limit (in the case $\sigma_f=7\cdot5$ kg.cm^{-2}) and for higher stresses still, a marked rehardening occurs ($\sigma_f=15\cdot0$ kg.cm^{-2}). Prolonged stressing at high amplitudes can, then, result in a form of work-hardening, following the initial recovery, and it may be that we have in these results the clue to the effects of overstressing or understressing. At least, it seems possible that if the rehardening process can be initiated at some high stress, but not strongly developed, then a resistance to lower stress fatigue may have been built up. This, of course, is conjectural and would need direct confirmation. The important fact is that such a recovery-inversion occurs at all, and having now established this fact, it is possible to examine its consequences with a more understanding reference to other results.

These results are limited in several ways, of course, in that a number of the test parameters are fixed. A full experimental survey would constitute an enormous task, but we can at least deal with the remaining time variable τ. The above results show how recovery after a fixed amount of work hardening in creep depends upon fatigue stress and duration. By fixing the duration, we may now examine how the recovery is affected by interruption at different points along the creep curve (i.e. at different τ values). The experimental results are given in Fig. 7. The rehardening feature again appears, for we see that for a fixed value of ρ (period of fatigue application) of 70 minutes, the curves in the inset (showing recovery against fatigue stress) for all the values of τ chosen go through a maximum. If the fatigue stress is very high, then under the conditions of slight residual static stress which existed in these particular experiments, creep occurs, and generally the damage may be so great that failure results almost at once on reloading.

The Handling of the Three Variables, ρ, τ and σ_f

From the foregoing, it will be evident that this admittedly restricted problem can be handled by introducing only the recovery index n. The situation may be summarised as follows. For isothermal, constant stress, but discontinuous (that is, interrupted) creep, the introduction of recovery, through the index n, enables the problem to be treated analytically. For identical conditions of creep, but with a fatigue stress present during the recovery periods, the nature of the behaviour can still be expressed in terms of n alone, but because of the complexity, not in analytical form, at least at present. The question, then, is whether such results, which concern the dependence of n on the three variables τ, ρ and σ_f, can be presented in any significant way which might ultimately link up with design methods for such cases. The best that can be done is to plot the quantity n, which is a measure of the resoftening of the material, against pairs of the variables. This has been done in Figs. 8, 9 and 10. The axes ρ^m and τ^m have been adopted instead of ρ and τ in cases where it is useful for the presentation.

The Nature of the Basic Processes

The physical processes which can occur in metals under complex stress and temperature conditions are numerous and lead not merely to deformation and fatigue damage, but to structural changes of various kinds. Such changes may be quite large in scale, as in the case of recrystallisation or phase transformation, or they may involve no more than the limited movements of groups of dislocations within regions of certain grains. A detailed study of this physical background is irrelevant here, but some brief consideration of its main features is needed if the engineering results are to be given their proper significance.

A discussion of the mechanical behaviour of metal crystals, either singly or in the aggregate, is not possible without introducing dislocations and vacancies into the argument. The fact that dislocation explanations have not always been well received in engineering does not detract from their undoubted success in many directions. There is, in any case, no other theory of anything like comparable stature at the present time and direct experimental evidence is constantly accumulating. Fatigue itself is a dynamic process exhibiting certain statistical features together with a cycle-dependent law of failure. Without active elements in the structure the accumulation, or counting, of fatigue cycles in the pre-crack stage is meaningless, and no more acceptable element can be devised than that of an elementary edge dislocation. It is, of course, true that whereas many of the basic ideas of dislocation theory can be demonstrated directly and convincingly by optical and electron microscopy, the processes into which they enter are more difficult to reveal and involve varying measures of theoretical conjecture. This can rightly be criticised in many ways, but it would be misguided to discard the whole concept of crystal imperfections because certain problems have so far proved intractable.

It is useful to start discussion of this question from the dislocation standpoint, because by adopting the concept of dislocation mobility as being one of fundamental significance, such physical phenomena as

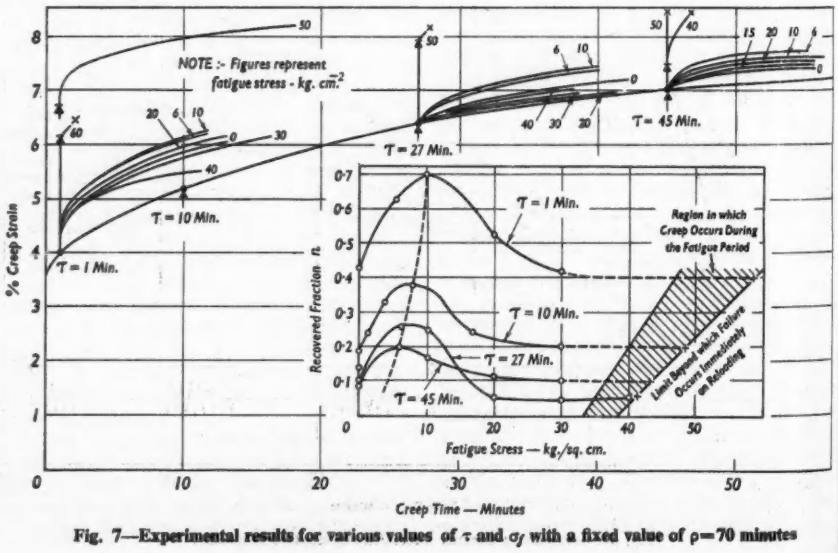

NOTE :- Figures represent fatigue stress - kg. cm.⁻²
% Creep Strain
Creep Time — Minutes
τ = 1 Min.
τ = 10 Min.
τ = 27 Min.
τ = 45 Min.
Recovered Fraction n
Region in which Creep Occurs During the Fatigue Period
Limit Beyond which Failure Occurs Immediately on Reloading
Fatigue Stress — kg./sq. cm.

Fig. 7—Experimental results for various values of τ and σ_f with a fixed value of ρ=70 minutes

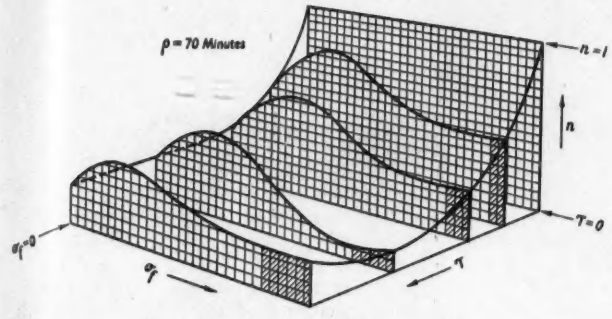


Fig. 8—The relationship between τ, σ_f and n

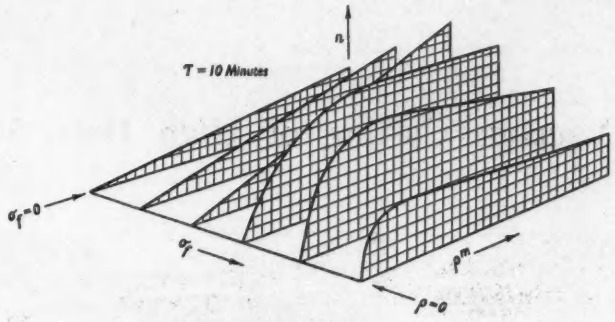


Fig. 9—The relationship between n, ρ and σ_f

hardness, or degree of coldwork, may be generalised, as it were, and the complexities of the problem followed through more easily.

In a fully-annealed metal, the dislocations are mobile (there are exceptions to this which we need not pursue here). As deformation occurs, under uni-directional stressing, dislocations are generated and move through the lattice, building up at barriers and creating localised internal stresses. The metal thus becomes more resistant to deformation, and although on the removal of the external stress a back diffusion of dislocations may occur, some other process is required if the observed degree of recovery, particularly at high temperatures, is to be explained. It is evident that as long as barriers exist to motion on a particular plane, then full recovery can never occur unless the dislocations concentrated on that plane can either cancel out or escape to others and thus by-pass the barriers which exist. It need only be said here that such a process of recovery is indeed sensible physically, as it is equivalent to the addition (or subtraction) of vacancies to an edge dislocation, effectively shifting the dislocation into a neighbouring plane. If the stresses are alternating, then so must be the dislocations, and it is here surely that we must seek the clue to the nature of the fatigue problem. It so happens that the intersection of certain types of dislocation creates a particular kind of dislocation feature which can be shown to generate vacancies by its movement through the lattice. Under alternating stresses this cyclic motion creates vacancies and collects these together into localised concentrations, which in turn reduce the mobility of the dislocations through the lattice. Ultimately, the stress

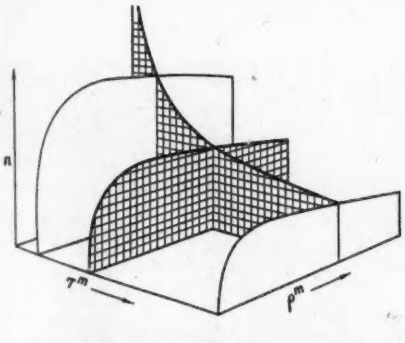


Fig. 10—The relationship between n, τ and ρ

concentration at the edge of such a vacancy cluster will initiate a crack, which, once formed, spreads by a quite separate mechanism, but preferentially along slip bands because these contain concentrations of internal stress.

This abbreviated account of a possible sequence of occurrences in the lattice is by no means the only one that could be proposed, but it does offer a basic framework against which the results described may be viewed and discussed, and thus shows up more clearly in what way research might be most usefully directed. It is apparent that the results reported may be interpreted in terms of vacancy generation by fatigue stresses, first, because such vacancies may accelerate recovery by shifting dislocations into neighbouring planes, and, secondly, because vacancy clusters may ultimately reduce mobility and promote cracking. Such a sequence is in accordance with the observations. Other theories exist, however, and much will remain conjectural until more critical experiments are undertaken. One outcome of the above work, of some importance, is that such critical experiments may now be much more readily designed.

Discussion

The results reported in this article were designed to elucidate the basic effects of fatigue, and it may now be said that these effects are almost wholly reconcilable with the assumption of an increased recovery. Even the accelerating effect on the creep curve is interpretable in this way, and it is interesting that this links up with an older view of steady-state creep as being a recovery-activated flow.

As they stand, these results are insufficient to offer a basis for a general design approach, and are useful at present only for special cases. Their importance, however, lies in the contribution they make to the evolution of more general methods, and it may be worth while to consider briefly the way in which such developments may be made.

The problem is to design within specified limits of deformation and fatigue damage under cycles of complex creep and fatigue stresses, and under associated cycles of temperature. Now that the whole of the deformation effects may be expressed in terms of work-hardening and recovery processes, then the required computation is essentially an integration of each process over the whole of the required working life. Such a problem would appear prohibitive were it not for certain possible simplifications. In the first place, experiment has shown that, for certain types of cyclic creep stressing at least, the creep curve envelope, or the mean creep curve, retains its original time function or functions, altering only in the coefficients which describe it. If such a simplification could be demonstrated to be valid for more general conditions, then the task of determining the actual creep strain over long times would be made much more economical. A relatively few history cycles (that is, actual complex cycles of creep and fatigue stresses and temperature) would then enable long-term behaviour, under repeated cycles of similar form, to be determined. The possibility that this may be a reasonable development is strengthened by the demonstration that fatigue may be viewed, from the creep point of view, as a recovery-promoting process, because no special processes need now be introduced to accommodate the action of fatigue.

Design methods for cumulative fatigue damage under such conditions are far more difficult to set out, particularly as there is no index comparable to creep strain on which to base the design. Various effects exist; for instance, as Fig. 7 shows, a material deformed by creep is more susceptible to fatigue damage and failure than one not so deformed. The use of fatigue data derived from standard tests can therefore be dangerously misleading when applied to assemblies in which either general or localised creep occurs. It is particularly important, therefore, where concentrations of stress exist, and where creep is known to occur, for the material to be fatigue tested after some prior deformation.

These are simply individual points which arise from the work. As has been said, more general fatigue design methods will not be advanced without much more experiment, and the handling of the data derived may prove impossibly difficult without the aid of special computers. Research into methods of handling such data is therefore becoming as urgent as the materials research itself and such innovations of material design may well prove the most distinctive feature of the developments of the next few years.

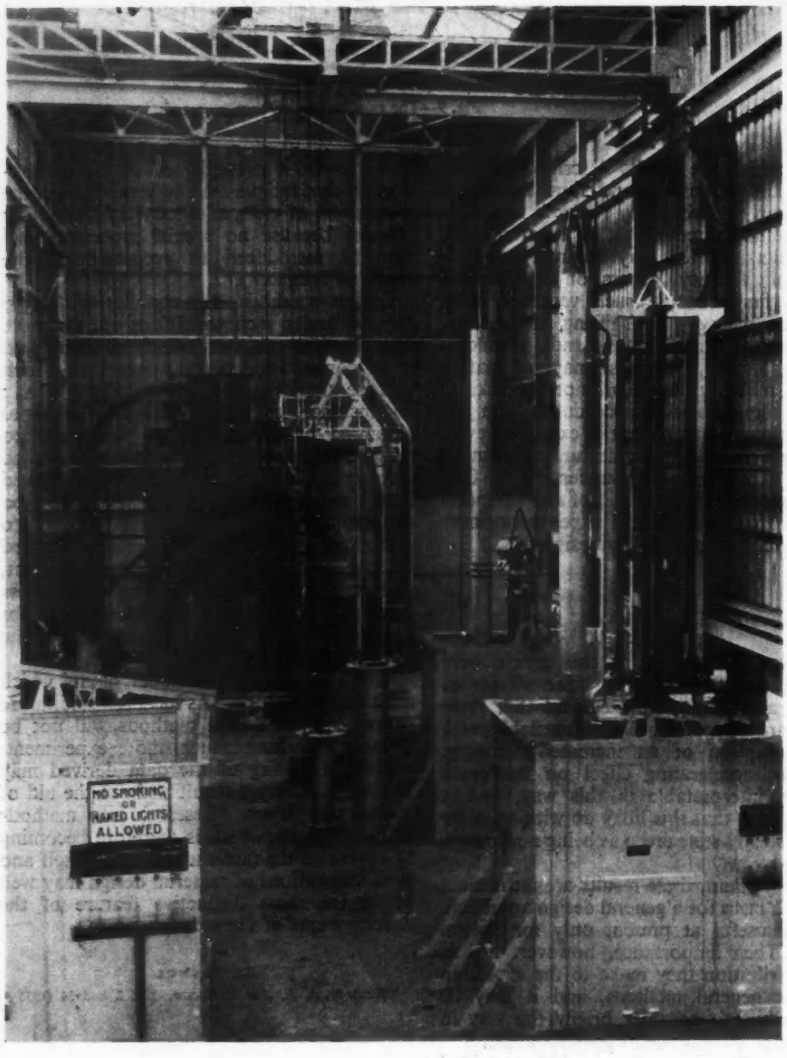
Reference

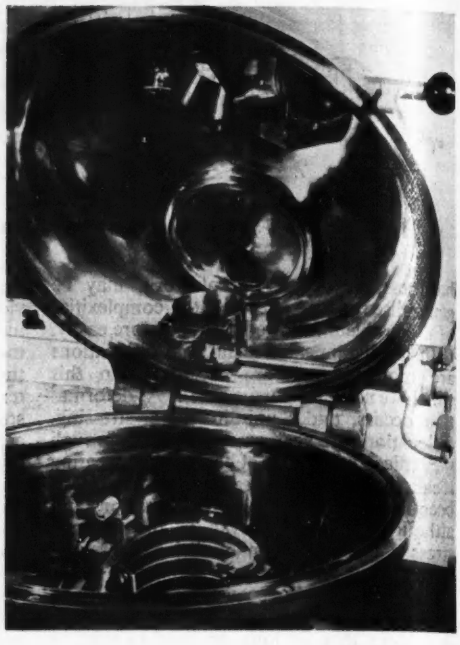
[1] Kennedy, A. J., The Engineer, 200, 2 and 34 (1955

Russian Study Tour of Britain's Hydro-Electricity

Nine Russian engineers arrived in this country on Tuesday, September 24, for a two-week tour of Britain's electrical power installations, particularly those of the North of Scotland Hydro-Electric Board. The visit has been arranged by the Soviet Relations Committee of the British Council in collaboration with the Institutions of Civil, of Mechanical, and of Electrical Engineers, and is a return visit following that paid by six British engineers to Russian hydro-electric installations last May. On Thursday morning, the delegation was due to fly to Glasgow, where the North of Scotland Hydro-Electric Board will act as host for an extensive tour of their works. Other technical visits will be to installations of the Central Electricity Authority; to the Mechanical Engineering Research Laboratory, East Kilbride; to John Brown and Co., Ltd., Clydebank; to Metropolitan-Vickers Electrical Co., Ltd., Manchester; to the Hydraulic Research Laboratory, Wallingford, and to Calder Hall.

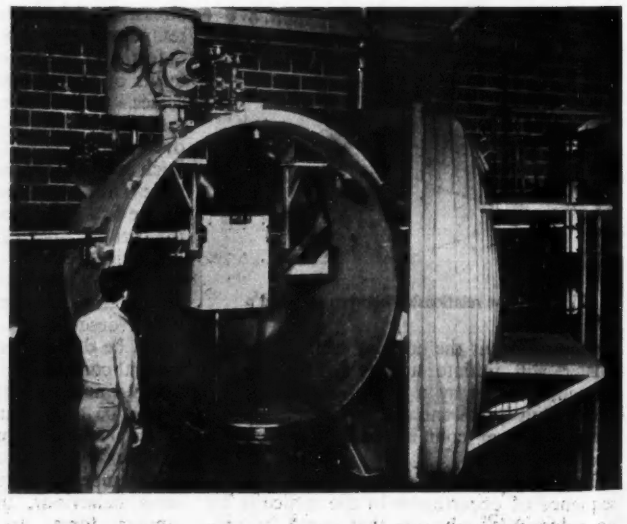
Vacuum Casting of High Duty Metals





The alloys of titanium are, as is well known, highly sensitive to oxygen and hydrogen content, and need to be melted in vacuum twice. The titanium melting department of William Jessop and Sons, Ltd., at Sheffield, seen on the left, is equipped to cast ingots up to 1 ton, and at present produces about five a week. Titanium granules and alloying additions are first mixed and then formed into a roughly semi-cylindrical block in the 2000-ton press in the background. A number of these blocks are then welded together to form a long bar to act as the consumable electrode in an arc furnace. One of the production furnaces is seen in the right foreground, with a smaller pilot plant beyond it. All were built in this country to National Research Corporation designs proven in the United States. Water-cooled copper crucibles are used, a small quantity of titanium being placed in the bottom to protect the copper from the initial striking of the arc, and in the first melt two 1000 lb electrodes are fused, one after the other, into an ingot. This ingot is then remelted into a larger crucible, the process taking about four hours. The moulds are slightly tapered, and the ingot withdraws under its own weight.

The current supply to the furnaces is by a number of selenium rectifiers, each with an output of 4000A at 20V. The furnaces are evacuated to 10μ mercury by oil diffusion and mechanical vacuum pumps in a basement, which is kept clear of personnel during a melt as a safety precaution. The same plant is also used for the vacuum melting of steel where particularly high quality is required as, for instance, in rolling bearings. For more highly alloyed steels induction furnaces are used; at the top is seen a small high-frequency furnace built by Gerastebau-Anstalt Balzers, with provision for pouring from the crucible into a mould and, in the lid, equipment for adding fresh constituents: this furnace is at the Whiston Research Laboratories. For production purposes a 600 lb furnace is to be installed; like the arc furnaces, it is a N.R.C. design built by Wild Barfield. A similar furnace in the U.S.A. is seen here. Samples of "Vacumelt" alloy steels were shown at the S.B.A.C. Exhibition.



Effect of Inertia on Wide Angle Flow in Hydrodynamic Lubrication

By J. F. OSTERLE* and W. F. HUGHES†

In theories of hydrodynamic lubrication propounded by Lewicki and Milne the contribution of lubricant inertia is neglected. It is here suggested that for flows in which the slider inclination angle is large the neglect of lubricant inertia can be a serious error. This article studies the matter qualitatively and quantitatively.

IN a paper[1] published in this journal in December of 1955, W. Lewicki presented what he called "an improvement on Reynolds' theory of (slider bearing) lubrication," in which he claimed to have taken into account the pressure build-up in the free space (flooded to infinity) in front of the slider, as shown in Fig. 1. His theory predicts a pressure at the leading edge of the slider substantially greater than the pressure at infinity, which is at variance with the usual assumption of Reynolds' theory that the

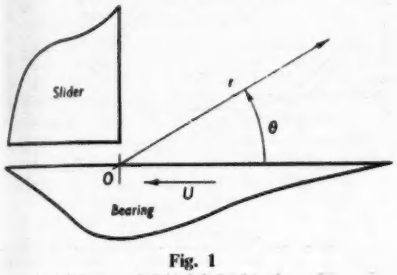


Fig. 1

pressure at the leading edge of the slider is negligibly different from the pressure at infinity. Less than a year later, in a paper[2] presented to the Ninth International Congress of Applied Mechanics (Brussels) in September of 1956, A. A. Milne, in analysing the slider bearing problem in which the slider inclination is not small (see Fig. 2), showed that when Lewicki's theory is applied to his problem the agreement is good even for slider inclination angles as great as 30 deg. Lewicki assumed purely radial flow in his

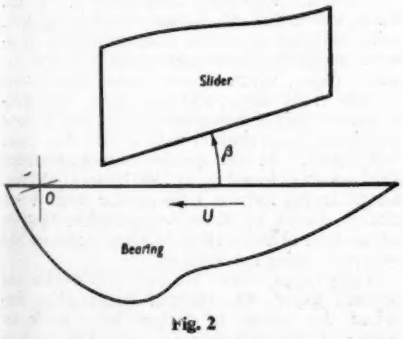


Fig. 2

work while Milne took the tangential velocities into account. However, in both theories (explicitly in Milne's and tacitly in Lewicki's) the contribution of lubricant inertia in the equation of motion is neglected. We submit that for flows in which the slider inclination angle is large (i.e. greater than several degrees) the neglect of lubricant inertia can be a serious error. We will show this to be true first qualitatively and then quantitatively, using results from a paper[3] co-authored by one of us on the effect of lubricant inertia in hydrodynamic lubrication.

For our qualitative argument we will use the equation of motion given by Lewicki (based on his assumption of purely radial flow) modified to take inertia into account. This equation is :

$$\frac{\partial p}{\partial r}=\frac{\mu}{r^2}\frac{\partial^2 u}{\partial\theta^2}-\rho u\frac{\partial u}{\partial r} \quad . \quad . \quad . \quad (1)$$

where r and θ are polar co-ordinates (see Fig. 1), u is the lubricant velocity in the r direction, p is the lubricant pressure, and μ and ρ are the lubricant viscosity and density, respectively. The first term in equation (1) represents the pressure force, the second term the viscous force, and the third term the lubricant inertia. The fluid must also satisfy a continuity equation which for this flow is :

$$\frac{\partial u}{\partial r}+\frac{u}{r}=0 \quad . \quad . \quad . \quad . \quad (2)$$

Substituting equation (2) into equation (1), we obtain :

$$\frac{\partial p}{\partial r}=\frac{\mu}{r^2}\frac{\partial^2 u}{\partial\theta^2}+\rho\frac{u^2}{r} \quad . \quad . \quad . \quad (3)$$

Noting the following orders of magnitude :

$$\frac{\partial^2 u}{\partial\theta^2}\approx\frac{U}{\beta^2} \quad \text{and} \quad \frac{u^2}{r}\approx\frac{U^2}{R}$$

where R is a characteristic dimension in the radial direction, such as slider length, we see that the ratio of inertia force F_i to viscous force F_v in order of magnitude is given by :

$$\frac{F_i}{F_v}=\frac{R\beta^2\rho U}{\mu} \quad . \quad . \quad . \quad . \quad (4)$$

which can be written :

$$\frac{F_i}{F_v}=\frac{h^2 U}{\nu R} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where h has been written for $R\beta$ and ν is the kinematic viscosity of the lubricant. For a medium oil ν is about 10^{-1} square inches per second so that if we consider U to be on the order of 10^3in per second, equation (5) reads :

$$\frac{F_i}{F_v}=10^3\frac{h^2}{R} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Now in the usual lubrication application (very small β) h is of the order 10^{-3}in, which for an R of 1in makes F_i/F_v equal approximately to 10^{-3}, which shows that the inertia force is extremely small relative to the viscous force, permitting the inertia effect to be neglected safely. However, if β is several deg. or more (as in the cases investigated by Lewicki and Milne), h will become orders of magnitude greater than 10^{-3}in. For example, if in the problem cited above β is about 6 deg., h will become of the order 10^{-1}in which, by equation (6), means that F_i will be roughly ten times greater than F_v. Inertia effect is certainly not negligible now. It appears then that for inertia effect to be truly negligible, the film thickness must be very small and consequently so must the angle of slider inclination.

For a quantitative argument we would like to refer to reference[3] which takes the lubricant inertia effect in hydrodynamic slider bearing lubrication into approximate account by a technique which averages the inertia terms in the equation of motion across the film. This approximation is, of course, applicable only to very thin films. Our analysis in this paper led to the following expression for the effect of lubricant inertia on the load capacity of a slider bearing :

$$\frac{\bar{p}}{\bar{p}_0}=1+k\frac{\rho U^2}{\bar{p}_0} \quad . \quad . \quad . \quad . \quad (7)$$

where $\bar{p}$ is the average pressure over the slider length with inertia considered and $\bar{p}_0$ is the same pressure with inertia neglected. The factor k is a function only of the minimum-to-maximum film thickness ratio which we will call r. In our paper we presented values of k for several values of r of interest in bearing design (see Table I).

TABLE I

r		k
1	...	0
$\frac{1}{2}$	...	0·00160
$\frac{1}{4}$	...	0·00568
$\frac{1}{8}$	...	0·01777

Note that the inertia effect increases as the slider inclination increases (r decreases). Using the same values of ρ and U as above and an average pressure (without inertia) of 100 lb per square inch, we would find that for an r of $\frac{1}{8}$ the inertia effect increases the load capacity by only $\frac{1}{2}$ per cent, which is indeed negligible. However, if r is taken to be 10^{-2} (which corresponds to about a 6 deg. inclination for a 1in slider), k works out to be 0·250, which means that in this case inertia would increase the load capacity by about 5 per cent, which is no longer safely negligible. For larger slider inclination angles the inertia effect would become even more serious ; but, of course, this approximate method for predicting load capacity, relying as it does on the smallness of the film thickness, cannot be expected to yield accurate results at large values of β.

In summary, then, it appears that to solve the wide angle problem posed by Lewicki and Milne, the inertia terms in the equation of motion must be taken into account to avoid serious error. Until this is done, the conclusions drawn by Lewicki and Milne from their work must be considered inconclusive.

REFERENCES

[1] "Theory of Hydrodynamic Lubrication in Parallel Sliding," by W. Lewicki, THE ENGINEER, December 30, 1955.
[2] "An Alternative Approach to the Theory of Hydrodynamic Lubrication," by A. A. Milne, Ninth International Congress of Applied Mechanics, Brussels, September, 1956.
[3] "On the Effect of Lubricant Inertia in Hydrodynamic Lubrication," by F. Osterle and E. Saibel, *Journal of Applied Mathematics and Physics*, Vol. 6, 1955, page 334.

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Turbo-Prop Operation

THE operation by British Overseas Airways of Bristol "Britannia" aircraft with "Proteus 705" engines has led to this engine, the only propeller turbine in a civil aircraft yet to use the free-shaft principle, increasing its overhaul life rapidly. Commencing at 500 hours, it became 650 hours in February and 850 in May, a figure which was reached by only 43 per cent of engines, 52 units having been damaged by ice or removed for modification, and now has been raised to 1050 hours.

A Certificate of Airworthiness has now been granted to the long-range "300" series with "Proteus 755" engines. However, the effects upon various gas turbines of icing conditions being still not fully resolved, there are certain climatic regimes in which prolonged flight is to be avoided. The performance of production series aircraft has shown that the machine on which prototype flying was done was not a good sample ; the prototype was deficient about 7 per cent in range, but production aircraft fully satisfy contract requirements.

Metallurgical Topics

Creep Tests

THE May/June number of *Archiv für das Eisenhüttenwesen*, 1957, is largely devoted to the subject of creep. In a series of eight papers the behaviour of heat-resisting steels in long-time creep tests at temperatures between 500 deg. and 700 deg. Cent. is described. In a foreword to these papers, K. Richard (page 245) describes how the co-operative research which has resulted in these papers originated. For the last thirty years there has been an urgent requirement for heat-resisting steels for boiler and turbine construction, and for a knowledge of their stress-bearing capacity. For a long time it seemed possible, with the help of short-time tests, to be able to judge the steel and ascertain its safe working stress. With the increase in working temperatures to over 500 deg. Cent., it became more and more evident that really long-time experiments were absolutely required if structural components were to be correctly designed. Tubes, for example, should obviously not be too thin; but, if too thick, they are not only uneconomical but temperature stresses are increased, with consequent danger of cracking. From such long-time studies as had been carried out, it was evident that at temperatures above 500 deg. Cent. the useful load-carrying capacity of heat-resisting materials was, for the most part, considerably lower than that which could be conjectured from short-time experiments. It was found, moreover, that at lower temperatures materials might be incorrectly rated by the use of short-time tests.

In 1949 a request was made by the Bayer Dyeworks at Leverkusen (where some long-time tests were being carried out) to the Materialprüfungsanstalt, Darmstadt, where facilities for such tests were available, to investigate the long-time creep characteristics of austenitic steels at 600 deg. Cent.; and arrangements were made between representatives of water-tube boiler and turbine manufacturers for similar work to be carried out at the Max-Plank-Institut für Eisenforschung at Düsseldorf. As a result, a programme of co-operative research was entered upon with the object of ascertaining, by long-time tests on all useful heat-resisting steels in the temperature range of interest, reliable 100,000 hour values for creep strength and strain. Further experiments served to ascertain the strength and deformation characteristics of certain steels in the welded condition. A microscopical study was also made to obtain information about structural alterations. Materials for the experiments comprised twenty-three ferritic and twelve austenitic steels, together with nine non-ferrous alloys. Several steels were tested as castings. Industrial products were employed. Whenever possible each steel was obtained from two producers, or at least two different melts were studied. For more than six years producers and users, and even competitors within the same group, have worked together for a common purpose.

In the first paper, by H. Reiner (page 247), the arrangements for carrying out the work are described and diagrams of the equipment employed are shown. Many specimens were accommodated in the same furnace. Length measurements, made at intervals to ±0·005mm, showed some irregularity (attributed to the material and not to the measuring apparatus) at the beginning of the test (up to about 1000 hours) but these died out after a longer time (5000 hours and more).

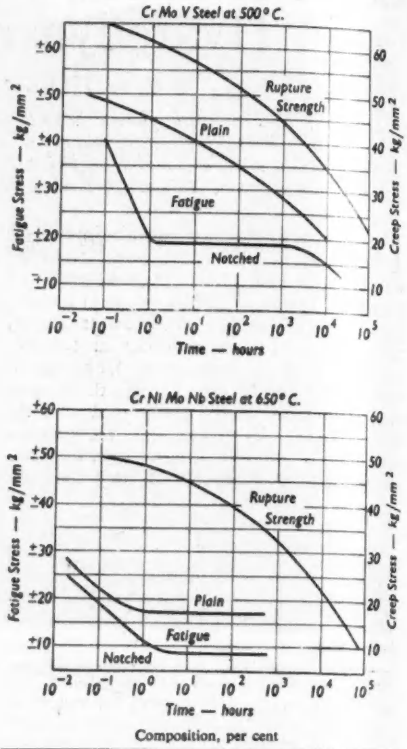
The second paper, by G. Bandel and H. Gravenhorst (page 253), dealt with assessment of the results, in the course of which the Larson-Miller relationship was examined. This was found to give good results by interpolation but, on account of marked scatter, extrapolation was only possible within a limited range of time, temperature, stress and extension.

Creep Tests on Ferritic Steels.—The third paper, by E. Jahn (page 259), gives detailed results of tests up to 50,000 hours on ferritic tube steels. Values were determined on plain, notched and in some cases welded specimens. The factor limiting their use was often a lack of resistance to scaling. Thus, the steel with chromium 2¼, molybdenum 1 per cent, which was superior to others at 600 deg. Cent., was resistant to scaling only up to 580 deg. Cent. The 5 per cent chromium-molybdenum steel, used in the chemical industry, was more resistant to scaling but had only medium creep resistance.

The fourth paper, by H. Holdt and P. Grün (page 269), contained a similar detailed report on the creep behaviour of ferritic constructional steels in tests which have so far lasted up to 50,000 hours. An increasing content of molybdenum (up to 2 per cent) and vanadium (up to 0·5 per cent) improved creep strength. Nickel content (up to 1·2 per cent) had no detrimental effect on the creep resistance of forgings which had been well tempered. Heat-treatment could effectually mask the influence of alloy composition. Unsuitable heat-treatment, especially quenching from too high a temperature in steels containing vanadium, and too low a tempering temperature, favoured a tendency to brittle fracture and increased notch sensitivity. The authors express the view that suitable heat-treatment temperatures for quenching and tempering, as well as intermediate treatments, must still be exhaustively studied in order to attain the best values for creep strength with absence of brittle fracture and a low notch sensitivity. The higher the chromium content (up to a certain point) the less was the tendency to brittle fracture. An exception to this was the steel with 12 per cent of chromium and 2 per cent of cobalt, in which a structural constituent (delta-ferrite) appeared to have a significant effect on behaviour at fracture. The fall in creep strength in several melts containing over 2 per cent and up to 6 per cent of chromium could be compensated by correct additions of molybdenum and vanadium.

Creep Tests on Austenitic Steels and Alloys.—In the fifth paper, by K. Bungardt (page 287), results of creep tests of 50,000 hours' duration are given for chromium-nickel steels with various alloy additions, chromium-manganese steels with additions of vanadium and nitrogen, complex chromium-cobalt-nickel-iron alloys, and two nickel alloys based on 80 : 20 nickel-chromium. Chromium-nickel and chromium-nickel-molybdenum steels with niobium additions had higher creep strength at 600 deg. Cent. than the corresponding steel with titanium. In chromium-nickel steels stabilised with niobium, but without further alloy addition, raising the nickel content from 10 to 13 per cent had a favourable effect. Raising the nickel from 13 to 16 per cent in niobium-stabilised chromium-nickel-molybdenum steel was without influence on the creep strength but improved toughness in the long-time tests. Simultaneous additions of niobium, vanadium and nitrogen raised the creep strength in comparison with that of chromium-nickel-molybdenum steel, containing niobium but no special nitrogen addition, up to about 650 deg. Cent., but the advantage was lost at 700 deg. Cent. The creep behaviour of 16 : 13 chromium-nickel steel, as well as of 16 : 13 : 2 and 16 : 16 : 2 chromium-nickel-molybdenum steels, was improved by a small boron content. Among the simple austenitic steels, the last-named had the highest creep strength, up to 700 deg. Cent. A further improvement was obtained on passing to the more complicated cobalt-bearing steels with a higher proportion of carbide-forming elements. This improvement continued in the chromium-cobalt-nickel-iron alloys with an increased amount of carbide-forming elements and iron less than 50 per cent. In 10,000 hour tests the strengthening effect of warm working was found to be effective in improving creep resistance of these alloys at 700 deg. Cent.

Metallographic Studies.—The sixth paper, by A. Krisch (page 305), contains a description of the electrolytic separation of the residues from three austenitic and two ferritic steels during 10,000 hour creep tests, and their subsequent examination. The austenitic steels were 17 : 11 : 0·4 chromium-nickel-titanium, 17 : 14 : 0·7 chromium-nickel-niobium and 17 : 12 : 2 : 0·6 chromium-nickel-molybdenum-niobuim; the ferritic steels, 0·3 per cent molybdenum and 1·2 : 0·6 : 0·2 chromium-molybdenum-vanadium. Whereas, the austenitic steels originally contained the carbides TiC or (Nb, Ta) C, after about 1000 hours at 600 deg. Cent., the carbide $M_{23}C_6$ was found in addition. After 6000 hours at this temperature the chromium-nickel-titanium steel began to show the sigma phase, which also appeared much more quickly in the test at 650 deg. Cent. The chromium-nickel-molybdenum-niobium steel showed the sigma phase only in tests at 650 deg. Cent. and above. In the chromium-nickel-niobium steel none was found up to 7500 hours at 650 deg. Cent. In the tests on both ferritic steels it was clearly shown by X-ray examination that an enrichment of the carbide in alloy elements had occurred during the creep test.



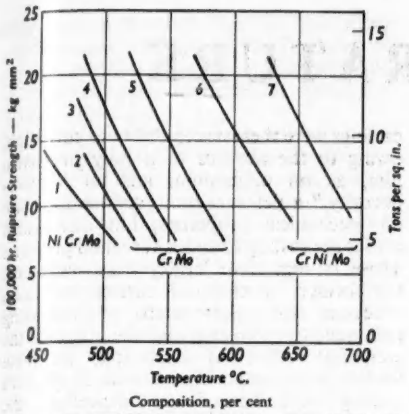
Composition, per cent

	C	Si	Mn	Cr	Mo	Ni	V	Nb
(1)	0·23	0·26	0·44	1·27	0·57	0·17	0·18	—
(2)	0·07	1·02	0·72	15·8	2·12	15·8	0·07	1·05

Treatment : (1) 950 deg. Cent./oil ; 5 hour, 580–680 deg. Cent./furnace.
(2) 20 minutes, 1100 deg. Cent./air.

Fig. 1—Rupture strength of plain specimens and endurance under alternating stress (plotted on a time basis) of plain and notched specimens of : (1) chromium-molybdenum-vanadium steel at 500 deg. Cent., and (2) chromium-nickel-molybdenum-niobium steel at 650 deg. Cent.

High-Temperature Fatigue Tests.—In the seventh paper, M. Hempel (page 311), describes the results of fatigue tests made on plain and on notched specimens of two steels at room temperature and at 500 deg. to 650 deg. Cent., and compares the data with those obtained under static stress. The steels were an austenitic steel (16 : 16 : 2 chromium-nickel-molybdenum with 1 per cent of niobium) and a chromium-molybdenum-vanadium ferritic steel (chromium 1·3, molybdenum 0·6, vanadium 0·2 per cent approximately). In the ferritic steel at 500 deg. and 550 deg. Cent. the smooth specimens had reached no limiting value for fatigue strength after 100.10^6 alternations or about 1500 hours' duration of the experiment, whereas a limiting value was observed in the notched test piece of the same steel and in both types of specimen in the austenitic steel. Examples are shown in Fig. 1. The ratio of fatigue strength of plain to notched specimen (notch sensitivity) of the austenitic steel at 20 deg. Cent., varied around



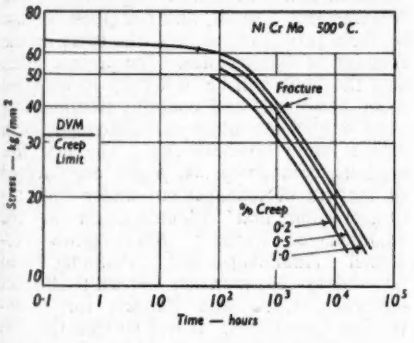
Composition, per cent

	C	Cr	Mo	Ni	Other elements
(1)	0·12	0·7	1·0	1·5	—
(2)	0·31	2·7	0·29	—	V 0·3
(3)	0·24	1·3	0·55	—	V 0·2
(4)	0·21	1·3	1·1	—	V 0·3
(5)	0·22	12	1·0	0·5	V 0·3
(6)	0·09	16	1·8	15	Nb 1·0, N 0·10
(7)	0·07	16·5	1·8	16·5	Nb 0·7

Fig. 2—100,000 hour rupture strength of various steels for bolts

unity ; at 550 deg. to 650 deg. Cent. it first increased and reached a constant value. The ferritic steel showed a higher value at 20 deg. Cent. At 500 deg. to 550 deg. Cent. it first rose and then fell continuously to a little over one. Plotted on a time basis, the fatigue curve fell considerably below the rupture strength curve for static stress, and reached a value in a few hours equal to that shown by the creep curve in 10,000 hours.

In the last of the eight papers, entitled " Some Provisional Conclusions," R. Schinn and W. Ruttmann (page 317) discuss the possibility of extrapolating from short-time tests to long-time values. They conclude that long-time values cannot be estimated from short-time tests. A Larson-Miller plot involving short-time tests at higher temperatures may show scatter up to 65 per cent, although a mean scatter of only about ±10 per cent is maintained. Structural changes in long-time exposure to high temperature may have an important effect. In another paper in the same journal, A. Krisch and W. Wepner (page 339) compare the experimentally determined creep curves of nineteen ferritic and



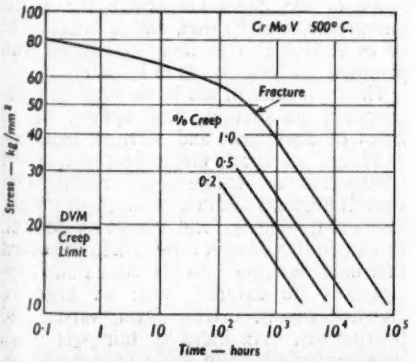
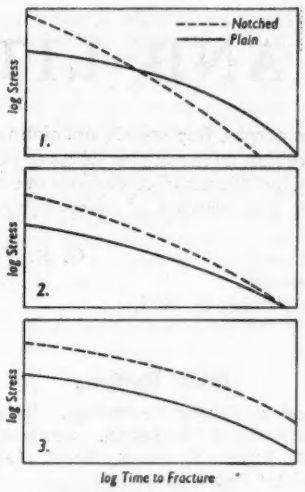


Fig. 3—Logarithmic stress/time curves at 500 deg. Cent. for a nickel-chromium-molybdenum steel (D in Table I) showing a tendency to brittleness, and a chromium-molybdenum-vanadium steel (J in Table I) giving a tough fracture



(1) Rapid embrittlement.
(2) Tendency to slow embrittlement.
(3) No tendency to brittle fracture.

Fig. 4—Diagram of relative positions of creep curves of plain and of notched specimens

nineteen austenitic steels at two or more temperatures by the method of Larson and Miller. They report that in most cases the agreement was bad, so that a uniform " master curve " could not be drawn for these materials. The experimentally determined creep strength for 10,000 hours, however, agreed with the calculated value within ±10 per cent if the creep strength for a temperature about 50 deg. Cent. higher were known, although in some cases an error of 40 per cent occurred. The scatter after 100,000 hours might be greater, but they propose to repeat the evaluation of this method when the 100,000 hour values are established experimentally. For some steels, however, Schinn and Rittmann give estimated values for rupture strength in 100,000 hours, based on tests up to about 50,000 hours. These values are shown in Fig. 2.

100,000 *Hour Creep Tests at 500 Deg. Cent.*—Although in the co-operative research actual tests do not seem to have, so far, extended to much beyond 50,000 hours, some actual tests lasting for more than 100,000 hours are reported by A. Thum and K. Richard in the same journal (page 325). Some typical results are given in Tables I and II, and two examples are shown in Fig. 3. Plain and notched specimens were tested. Initially the notched specimens always gave the higher value. In many steels the curves for the notched specimens lay wholly above those for the

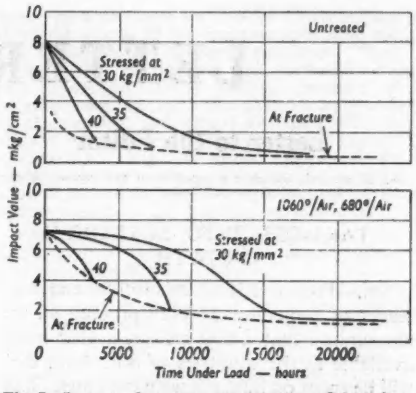
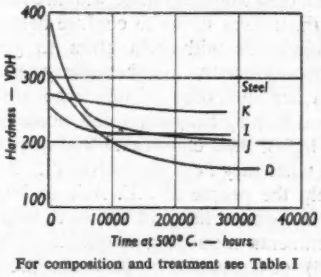


Fig. 5—Impact value at room temperature of chromium-molybdenum-vanadium-tungsten steel (K in Table I) after being heated under stress at 500 deg. Cent.

plain specimens ; these steels showed no brittle fracture on long-time stressing. In other steels the lines approached one another or even crossed, indicating a tendency to brittle fracture (Fig. 4). Long-time stressing may produce considerable structural damage before rupture. By measurement of the impact value the extent of this damage may be estimated (Fig. 5). Softening also has an important influence (Fig. 6). Comparison of actual long-time values with the DVM creep limit of the materials studied demonstrated the well recognised fact that no relationship exists between the results of this short-time test and the long-time value for resistance to creep.

These papers provide valuable data obtained from long-time tests on a great variety of steels and illustrate some of the factors known to influence behaviour under stress at high temperatures, but they do not appear to introduce any new principles into creep-testing procedure.



For composition and treatment see Table I

Fig. 6—Softening of heat-treated steels after long-time stressing at 500 deg. Cent.

TABLE I—*Composition and Heat-Treatment of Some of the Steels Studied (Thum and Richard)*

	Type	Composition, per cent						Heat-treatment, deg. Cent.
		C	Si	Mn	Cr	Mo	Other elements	
A	Carbon	0·22	0·24	0·52	—	—	—	Normalised
B	Carbon	0·33	0·30	0·64	—	—	—	As rolled
C	CrMo	0·25	0·25	0·51	1·13	1·11	—	980 deg./air, 640 deg./air
D	NiCrMo	0·11	0·22	0·46	0·72	0·88	Ni 1·53	870 deg./oil, 590 deg./air
E	NiCrMo	0·15	0·23	0·39	0·87	1·03	Ni 1·48	980 deg./air, 610 deg./air
F	NiCrMo	0·20	0·48	0·53	0·78	0·94	Ni 0·91	950 deg./air, 620 deg./air
G	CrV	0·18	0·23	0·53	1·50	—	V 0·34	950 deg./air, 750 deg./air
H	CrMoV	0·30	0·27	0·51	1·61	1·28	V 0·10	950 deg./air, 680 deg./air
I	CrMoV	0·22	0·38	0·53	1·62	0·43	V 0·39	950 deg./oil, 680–690 deg./air
J	CrMoV	0·31	0·37	0·61	2·58	0·26	V 0·48	850 deg./water, 600 deg./air
K	CrMoVW	0·19	0·36	0·34	2·71	0·51	V 0·74 W 0·48	1060 deg./air, 680 deg./air
L	Cr ferritic stainless	0·06	0·28	0·30	19·85	0·96	—	750–800 deg./air
M	CrNi austenitic stainless	0·10	0·60	0·62	18·00	—	Ni 8·40 Ti 0·67	1030 deg./water

TABLE II—*Rupture Strength at 500 Deg. Cent. of Steels Referred to in Table I (Thum and Richard)*

	Type	Rupture strength in kg/mm² of plain specimens				Duration of test, hours	DVM creep limit at 500 deg. Cent., kg/mm²†	Ratio notched to plain*
		0·1 hour	1000 hour	10,000 hour	100,000 hour			
A	Carbon	25	8	5	3	106,000	3·5	1·07
B	Carbon	36	11	7	4·6	100,000	9	1·2
C	CrMo	61	38	25	16	130,000	26	0·78
D	NiCrMo	67	38	21	11·5	82,000	>30	0·91
E	NiCrMo	62	35	23	15·5	135,000	>28	0·78
F	NiCrMo	67	35	22	13·5	110,000	36	0·78
G	CrV	38	21	15·5	11·5	110,000	14–15	0·87
H	CrMoV	58	35	26	18·5	140,000	31·2	0·81
I	CrMoV	58	32	23	16·5	120,000	35	0·79
J	CrMoV	82	35·5	19·5	10·5	125,000	19·2	1·0
K	CrMoVW	60	43	34	23	127,000	35	0·72
L	Cr stainless	48	39	31	24	140,000	22–24	1·2
M	CrNi stainless	45	39	31	24	140,000	18–22	1·12

* Ratio of 100,000 hour rupture strength of notched specimen to the 100,000 hour rupture strength of the plain specimen.
† The DVM test is similar in principle, but not in detail, to the Hatfield time-yield test.

LETTERS AND LITERATURE

Letter to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

TAKE-OFF INTO SUSTAINED GROWTH

SIR,—Professor Blackett's lecture and your leader of September 13 both proceed on the assumption that £1000 million a year made available to the countries of S.E. Asia, &c., will be spent on humanitarian purposes. This admirable sentiment seems to lead to some misapprehensions of the facts and the logic of the situation. For instance, the statements that these countries threw off alien rule and that the U.S.S.R. has lifted itself by its own boot-straps are not precise descriptions of complex historical processes. And the opinion that financial aid from the "Free World" will prevent the adoption of communist methods of governing is unjustified: the Nazis and the Fascists adopted similar methods in industrially developed countries. The methods adopted to achieve objectives depend partly on the objectives and partly on moral ideas and standpoints, these standpoints—with due respect to K. Marx—not being determined by the current mode of production.

Professor Blackett's statement that outside aid can only fully help those who are ready to help themselves seems to confuse help given to individuals with help given to governments. Modern, non-hereditary governments are composed of men who are very good at helping themselves and, according to their lights, their countries. The question is as to what they help themselves to. Are we to help the people of S.E. Asia to improve their living conditions, or are we to help their governments in building up tyrannical (totalitarian) governments? Relevant are such facts as the Indian Government spending some 50 per cent of its income on defence and their keeping men under detention without trial; also rules governing the appointment of school teachers which seem like communist procedures—if one may mention such matters without discourtesy.

Professor Blackett is a bit elusive about why Britain took off without outside help around 1800. The men mainly responsible were capitalists motived by the then respectable but now disreputable hope of private profit and, in helping themselves, they helped others according to rules expounded by classic economists from Adam Smith through the Utilitarians to George Swartz. But governments spurn the sordid profit motive and pursue political power, prestige and national glory, which objectives correspond to Professor Blackett's term applied to individuals "ostentatious living" more than to his quotation from Humphrey Davy.

It seems that the problem of introducing some sort of law and order among national governments is more urgent than that of helping S.E. Asia, &c., to take off. Until that is achieved it might be wise to give financial help only to those governments who are morally on our side, the test of morality in this regard being the extent to which they agree in practice with us in such matters as habeas corpus, free speech, appointments to jobs without reference to religious or political beliefs, and the use of confessions in evidence against men accused of crimes against the State.

O. R. TUCKER

Braunston,
September 19, 1957.

Book Reviews

Magnesium Casting Technology. By A. W. BRACE and F. A. ALLEN. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 21s.

THERE has been a great increase in the output and variety of magnesium alloy castings during the post-war years. Their uses are reviewed and illustrated by a number of photographs in the last chapter of this book. This expansion of the industry has been made possible by modifications of composition and by improvements in the special foundry technique applicable to magnesium and its alloys. Differences in practice have arisen in this and other countries and in this book, initiated by the late Mr. F. A. Allen and completed and brought up to date by Mr. Brace, a successful attempt has been made to assemble the widely scattered information on the subject. The chemical and physical characteristics of magnesium and its alloys are very different from those of other metals employed as castings, and a specialised procedure must necessarily be adopted in the magnesium foundry. Melting practice, moulding and core sands, the production of sand castings, of gravity die castings and of pressure die castings are described in detail and illustrated by drawings and photographs, but at the same time a clear account is given of the underlying principles and the theoretical justification of the practical operations.

The development of magnesium alloys containing zirconium has been the outstanding achievement of the post-war period. The relative merits of the usual British method of adding the zirconium in the form of a master salt and flux, and the American technique of adding a 70 : 30 magnesium-zirconium hardener (or alternatively the direct addition of zirconium sponge) are discussed. While the "master salt" method seems to have the authors' support, they admit that further independent work to establish more precisely the relative merits of these methods is desirable. It may be noted that, as a result of experiments with magnesium-zinc-zirconium alloys, the N.P.L. now advocates the direct addition of metallic zirconium in the form of machinings or powder by melting the metals together under argon in a solid steel crucible. No fluxes are used in this method, which is said to give clean alloys with good mechanical properties. The still more recently developed alloys containing the rare earth metals and particularly thorium are fully dealt with. The magnesium-zinc-zirconium-thorium alloys are expected to find increasing application on account of their good creep properties in the temperature range 250 deg. to 350 deg. Cent. Special attention is given to the details of heat-treatment, which has played an important part in the development of magnesium alloys with improved mechanical properties. British and American practice are compared.

Factors which, in the early days, proved to be obstacles to the wider use of magnesium castings were their susceptibility to corrosion, owing to the absence of a fully protective film, as on aluminium, and to "microporosity," a defect without serious influence on mechanical properties, but one which causes the casting to leak under fluid pressure. These failings have largely been overcome, the former by chemical surface-protection processes and other means of improving resistance to corrosion, and the latter by the combined effect of degassing, adequate feeding and composition of the alloys. In dealing with methods of inspection, the authors commend the use of radiography as an aid to the provision of consistently sound castings at an economical price. A narrow view of acceptance tests is avoided and it is shown how various inspection methods may be used to control production and improve the product.

The book is a valuable contribution to the subject. It will appeal to the experienced foundryman because of its careful assessment of alternative methods of dealing with difficulties peculiar to magnesium castings, and it may be recommended to the student and newcomer to the industry which, in the authors' words, "is young enough for the novice of to-day to become the innovator of tomorrow."

Maintenance Engineering Handbook. By L. C. MORROW. McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 150s.

THIS book of over 1550 pages, with many illustrations, follows the pattern of other American handbooks in the presentation of fundamentals, methods, equipment, materials and reference data. The contents are written by more than eighty specialists under the guidance of the consulting editor of the McGraw-Hill "Industrial Organisation and Management" series, and compiled for use by those people in industry who carry on the function of maintenance. The preface states that the book will be of service to management personnel, and contains treatment of the management phases of maintenance to an extent found nowhere else. The first five sections, comprising 300 pages, are devoted to matters of management under titles:—Organisation and Administration of the Maintenance Forces; Maintenance Personnel Administration; Planning and Scheduling Maintenance Work; Project Control; Costs and Budgets for Maintenance Operations. It will be seen that the scope of the handbook covers the widest interpretation of its title, and is intended to be of service also to those concerned with planning and production in industry.

The remainder of the book deals with the selection, installation, and upkeep of all kinds of equipment and services, including buildings, electrical, mechanical service and transportation equipment, maintenance stores, lubricants and lubrication, instruments, sanitation, welding, and corrosion control. Production equipment is treated to the extent that units entering into its design and construction are covered, such as bearings, clutches, chains, drives, gears, valves, and instruments. An index of thirty-six pages provides an adequate guide to the volume. This new handbook contains comprehensive details of maintenance engineering as practised in the U.S.A., and should be of assistance to those engaged in industry.

Guide Book to Research Data for Arid Zone Development. Edited by B. T. DICKSON. United Nations Educational, Scientific and Cultural Organisation. H.M. Stationery Office. Price 25s.

THE United Nations has been active now for a number of years in drawing attention to development of the world's arid zones. Conferences have been held from time to time, and various publications—of which this one is the ninth—have been issued. The aim of the book is not that of a work of reference, but it tries to describe in outline all the various factors which must be taken into account if development of an area in the arid lands is to be undertaken with some prospect of success. The chapter headings give the best idea of these differing factors : mapping, climatology, geology and geomorphology, hydrology, soil resources, vegetation and forestry, all grouped together as "Physical and Biological Factors," and then, in Part II, "Human Factors," namely, population, land tenure, animal husbandry, nutrition, health and sanitation, and sources of energy. Each of these chapters is written by a United Nations technical officer, or someone who has been connected with Uno's research on arid zones. There is an introduction by the editor, who is the Australian member of Uno's arid zone committee. Each chapter aims at giving a general account of the specific problem with which it deals, so that a bird's-eye view of the whole range of development problems is given, rather than the finer points of technicality.

Engineering interest is restricted principally to the chapters on hydrology and on sources of energy. Nevertheless, the development problem as a whole is one of special interest, even to those concerned with only one aspect of it. The breadth of view characteristic of a consulting engineer's approach to such development is also well served by this generalised presentation.

An annual rainfall of 10in per year or less is taken for a rough classification of the areas designated "arid zones." About 6400 million acres, which is about a quarter of the land surface of the earth, falls within this designation.

Perspective Drawing for Technical Illustrators and Draughtsmen. By P. MANKTELOW. George Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2. Price 30s.

INFORMED contributions to the very small existing stock of publications designed to aid the intending technical illustrator are of especial interest, since there came recently into being the new City and Guilds Syllabus No. 228—"Technical Illustration." *Perspective Drawing for Technical Illustrators and Draughtsmen* is unquestionably in the class to which we have referred, though it is unlikely, if used as a textbook, to take the student very much further than the end of his second year's work under the syllabus.

Mr. Manktelow has approached his subject in an easily read, interesting style which should do much to attract the illustrator on the threshold of his career ; the repetition of the same simple object in a number of different views is a decided help in gaining a clear understanding of the teaching. On the other hand, it seems a matter for some regret that so much space has been devoted to a discussion of the perspective grid, which, whilst a useful "tool," in itself, cannot replace a sound knowledge of and constant practice in the basic forms of perspective drawing, and may indeed easily lead the tyro into a difficult situation. The inclusion of a chapter on measuring point perspective would have been a useful addition. The examples of "finished work" displayed in Chapter VI should encourage and generally prove helpful to the student, by defining the nature of some of the less complex illustrations which he will later be expected to produce. There is, however, little guidance in the book on the "laying-out" stage through which such drawings must pass when being transformed from their original orthographic form—often consisting of a set of component part drawings—to the "perspective fundamentals" shown in the insets.

Basic Mathematics for Radio and Electronics. By F. M. COLEBROOK, B.Sc., and J. W. HEAD, M.A. (Cantab). Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 17s. 6d.

THIS book was originally published under the title *Basic Mathematics for Radio Students*, being intended primarily for readers interested in radio or electronic engineering, who felt that their understanding of the subject was restricted by their ignorance of mathematics. In the third edition new material has been added and the scope of the text has been widened considerably. The first seven chapters, which were written by the late Mr. Colebrook, have been retained completely ; they deal with elementary algebra, indices and logarithms, equations and complex numbers ; continuity, limits and series ; geometry and trigonometry ; differential and integral calculus ; and the applications of these mathematical ideas to radio. Throughout, the treatment is elementary, with emphasis on basic concepts rather than detailed development and the style is commendably lucid.

The two new chapters which have been added by Mr. Head are concerned with the elements of operational calculus and of matrices with not more than two rows and columns, and some notes on miscellaneous matters, such as numerical computation and normal distributions. Mr. Head's initiative in introducing these complex subjects into an elementary textbook is justified by the result. The reader is made to feel not that he is tackling something difficult, but, rather, that he is being encouraged to start an intriguing exploration.

Books of Reference

Handbook of British Refrigeration Material, 1957. Eighth edition. Modern Refrigeration, Refrigeration House, Woking, Surrey. Price 25s.—The new edition of this handbook is well illustrated throughout with photographs and drawings of various items of power and plant equipment, insulator and refrigerator contruction and instruments. There is a directory of the refrigeration industry set out in alphabetical order, followed by a list of refrigeration materials associated with the names of manufacturers and suppliers. The remainder of the handbook consists of four sections which deal with machinery, power and plant equipment, insulation and refrigerator construction, and instrumental equipment respectively.

Aluminium in Shipbuilding. The British Aluminium Company, Ltd., Norfolk House, St. James's Square, London, S.W.1.—This book opens with a brief survey of the economics of aluminium alloys in ship's structures and goes on to list the materials recommended and discuss points of fundamental design. Notes on constructional details and equipment items are given followed by advice in the various shipyard operations involved, such as working the material, welding, and riveting. Successive sections of the book include particulars of physical and mechanical properties of the alloys, together with dimensional tolerances and sizes available. Appendices include tabular statements of mechanical properties of plate, sheet, castings and extrusions ; dimensions and properties of sections and tables giving suggested scantlings for deck houses and light superstructures.

British Petroleum Equipment. 1957–58 edition. The Council of British Manufacturers of Petroleum Equipment, 2, Princes Row, Buckingham Palace Road, London, S.W.1. Price 50s.—The volume opens with a note upon the work of the council and names the officers of the executive committee and those on the various advisory committees. There follows a list of members and addresses and brief descriptions of the principal products of individual members. In the next section is a classified list of equipment and services associated with the names of suppliers, while the major part of the book, amounting to about 700 pages, consists of the members' catalogue entries. Here specifications and technical data of the products manufactured by the member companies are described and illustrated.

British Chemicals and their Manufacturers. The Association of British Chemical Manufacturers, Cecil Chambers, 86, Strand, London, W.C.2. Free.—This is the 1957 Directory of the Association and in the first part there is a list of members, each being given a code number and being allocated certain letters representing the specific groups of chemical industries with which the particular firm is concerned. A directory of members and affiliated associations, is followed by a classified list of products against each of which is set the code numbers of the manufacturers. Similar treatment is accorded to indicators and microscopical stains. The final sections of the directory contain proprietary and trade names and proprietary and trade marks.

Merchant Ships, 1957. Adlard Coles, Ltd., 7, Brunswick Place, Southampton. Price 30s.—The 1957 edition of *Merchant Ships : World Built* contains particulars of ships of 1000 tons gross and upwards delivered in 1956 ; it is divided into twenty sections, with an introduction by A. C. Hardy. In section one brief statistics of shipbuilding in 1956 are given, followed by a list of owners and their new ships. The following sections are devoted to individual countries arranged in alphabetical order. Each section reviews the shipbuilding activities of the country, lists the shipbuilders and the ships built by them, and includes photographs and particulars of ships of particular interest. There is an alphabetical register of ships completed in 1956 which records dimensions, power and speed, and this is followed by a five-year cumulative index which indicates in which volume the particulars of the ship may be found.

Technical Reports

Le Mécanisme de la Coupe des Métaux. By Roger Jouty. Publications Scientifiques et Techniques du Ministère de l'Air, No. 326. Service de Documentation et d'Information Technique de l'Aéronautique, Magasin C.T.O., 2, Avenue de la Porte-d'Issy, Paris (15e). Price F.fr.1600.—In reviewing, at the beginning of his paper, the existing theories on the subject of the cutting of metals by cutting tools, the author criticises the scarcity of data as regards the range of cutting angle employed. For this reason, a number of experiments were carried out in order to remedy the deficiency. Of particular interest is that part of the paper where the cutting force and the heat produced are evaluated. With tungsten carbide tools operating at minimum speed, the chips are brought to near melting point, at least with a thin layer, and it is to this fact that the cutting efficiency is due. Finally, Monsieur Jouty examines the problems of vibration and the forces to which vibrations are due.

Photoélasticité Tridimensionelle, Aspects Théoriques et Expérimentaux. By C. L. Gaudfernau. Publications Scientifiques et Techniques du Ministère de l'Air, No. 330. Service de Documentation et d'Information Technique de l'Aéronautique, Magasin C.T.O., 2, Avenue de la Porte-d'Issy, Paris (15e). Price F.fr.1200.—In her doctorate thesis, Madame Gaudfernau presents the problem of three-dimensional photoelasticity both from the point of view of optical theory and of mechanics. A simple solution is established for finding the three principal axes at any point by way of finding the optical axes. The solution can be expressed in the form of a graphical construction ; the application of electronic computers to this problem is also shown.

Books Received

The Management of Design. The Council of Industrial Design. The Design Centre, 28, Haymarket, London, W.1. Price 3s. 6d.

Thermal Stresses. By B. E. Gatewood. McGraw-Hill Publishing Company, Ltd., 95, Farringdon Street, London, E.C.4. Price 56s. 6d.

Sheet Metal Work. By R. G. Blackburn and J. Cassidy. Edward Arnold (Publishers), Ltd., 41, Maddox Street, London, W.1. Price 14s.

American Civil Engineering Practice. Volume 3. By R. W. Abbett. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 200s.

Cost Finding in the Non-Ferrous Metals Industry. The British Non-Ferrous Metals Federation, 132, Hagley Road, Birmingham, 16, Warwickshire. Price 42s.

Hanningfield Water Supply

A water supply scheme in South Essex which will ultimately yield 21·5 m.g.d. was inaugurated last week. It consists of river intakes and a pumping station and mains supplying a large reservoir and treatment works built in a valley in the clay hills at Hanningfield. The scheme utilises the last major source of water in Essex.

OVER the past ten or twelve years, a good proportion of the effort of the civil engineering industry has been directed into schemes for water supply throughout the country, and many large new schemes have been completed. In south-eastern England particularly, when describing new schemes from time to time as they reached completion, we have drawn attention to the increasing development of water resources which are now approaching complete utilisation in many south-eastern regions. The Hanningfield scheme in South Essex, which was inaugurated by the Minister of Housing and Local Government, Mr. Henry Brooke, on September 19, illustrates this tendency. It is a large scheme, with a long-term yield of over 20 m.g.d., but it is the last major source—of, say, over about 1 m.g.d.—in Essex. It is also illustrative of the difficulty which this area presents—again a characteristic of much of south-eastern England—to the water engineer who needs both a copious supply and a good reservoir site. The catchment in which the reservoir is built is relatively insignificant to the scheme, and water is pumped to the reservoir from intakes on the rivers Chelmer and Blackwater at Langford, which is far enough up the Blackwater to give an intake unaffected by tidal conditions.

Principal Data for the Hanningfield Water Supply Scheme

River intakes at Langford :	
Statutory power of abstraction	43 m.g.d.
Capacity of Blackwater intake (approx.)	25 m.g.d.
Capacity of Chelmer intake (approx.)	25 m.g.d.
First stage delivery to Hanningfield reservoir	25 m.g.d.
Second stage delivery to Hanningfield reservoir	35 m.g.d.
Length of pipeline to reservoir	8·9 miles
Diameter of pipeline	48in
Head on pumps	278ft
Pumps at Langford :	
First stage installation	2 large and 2 small sets
Additional installation for second stage	2 large sets
Large set :	
Capacity	4860 g.p.m.
Operating speed	986 r.p.m.
H.P.	490
Small set :	
Capacity	2430 g.p.m.
Operating speed	988 r.p.m.
H.P.	247
Reservoir :	
Estimated dry weather yield of scheme	21·5 m.g.d.
Catchment area draining directly into reservoir	5 square miles
Catchment area of rivers Chelmer, Ter and Blackwater	377·5 square miles
Average annual rainfall	23·1in
Capacity of reservoir	5968 m.g.
Top level of main embankment... ...	186ft A.O.D.
Top water level of reservoir	181ft A.O.D.
Top water area of reservoir	874 acres
Maximum depth of water	55ft
Main embankment :	
Height above site excavation	64·5ft
Length	6850ft
Maximum bottom width	440ft
Cubic content	1,186,000 cubic yards
Length of cut-off trench	6940ft
Maximum depth below ground of cut-off trench	32ft 4in
Length of road diversions	2·85 miles

From Langford, water is pumped for 9 miles, and against a head of nearly 300ft, to the Hanningfield reservoir. The reservoir site is one of the highest valleys in the hills of this area where the predominant substrata are clay. A large treatment works has been built close to the reservoir, where water is softened and purified, and then pumped into supply. Two supply systems are served, that of the South Essex Waterworks Company, and that of the Southend Waterworks Company, and the scheme has been promoted by a joint managing committee formed on behalf of the two companies. The principal statistics of the scheme are listed in the accompanying table. It is described in greater detail in the ensuing text, and various aspects of it are illustrated in the figures.

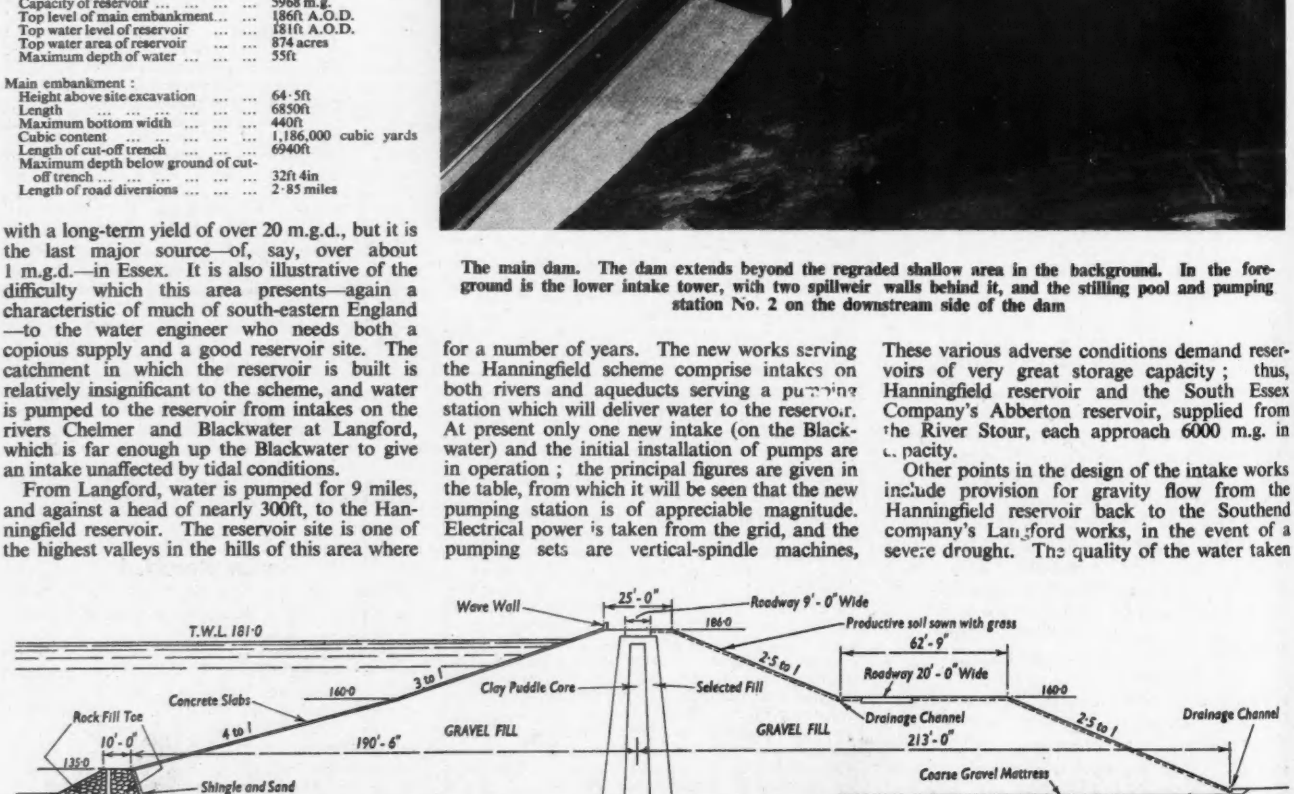
Langford Intakes and Pumping Station

A supply scheme has been operated by the Southend Waterworks Company at Langford for a number of years. The new works serving the Hanningfield scheme comprise intakes on both rivers and aqueducts serving a pumping station which will deliver water to the reservoir. At present only one new intake (on the Blackwater) and the initial installation of pumps are in operation ; the principal figures are given in the table, from which it will be seen that the new pumping station is of appreciable magnitude. Electrical power is taken from the grid, and the pumping sets are vertical-spindle machines, generally built along conventional lines. The electric motors driving the pumps can be operated with a speed variation of 10 per cent.

The figures for rates of abstraction from the two rivers and those for the pipeline capacity and yield of the scheme may be compared. Essex shares with Northampton the distinction of having the lowest rainfall of any county. Losses by evaporation and absorption by crops are nearly independent of the rainfall, so when the rainfall is little in excess of these losses no large quantity of water can be collected. An additional 4in or 5in of rain thus makes a great difference both to the supply from wells and the flow of rivers. In the years 1932 to 1955 the Thames catchment had an average rainfall of 28in a year and the flow in the river represented 9·43in of this, the losses being 18·57in. The rivers Chelmer, Ter and Blackwater catchments received an average of 23·37in of rain and discharged 3·78in, the losses being slightly higher at 19·59in. Hence it comes about that these Essex rivers, while having only 16·5 per cent less rainfall, actually discharge 60 per cent less water. In the great drought of 1933–1935 the flow of these three Essex rivers fell to but little over 3½ m.g.d. for a period of several weeks from a drainage area of 377·5 square miles. These various adverse conditions demand reservoirs of very great storage capacity ; thus, Hanningfield reservoir and the South Essex Company's Abberton reservoir, supplied from the River Stour, each approach 6000 m.g. in capacity.

Other points in the design of the intake works include provision for gravity flow from the Hanningfield reservoir back to the Southend company's Langford works, in the event of a severe drought. The quality of the water taken

The main dam. The dam extends beyond the regraded shallow area in the background. In the foreground is the lower intake tower, with two spillweir walls behind it, and the stilling pool and pumping station No. 2 on the downstream side of the dam



Typical cross section of the main dam. Its length is 6750ft, and the reservoir impounded by it will hold almost 6000 million gallons

The treatment works. In the foreground are (right) the supply chamber, and (left) the works substation, with the boiler-house behind it. From left to right the principal elements of the treatment works are the chemical house, four "Accelators," the CO_2 contact tank, rapid-gravity-filter house, and covered service reservoir with the main pumping station behind it

into the scheme at Langford is to be improved by the exclusion of sewage effluents from the two nearest urban areas—Chelmsford and Witham. Effluent mains are envisaged from the treatment works serving both these areas, extending in each case for about 3½ miles, to the tidal part of the Chelmer.

Hanningfield Reservoir

The principal reservoir work—the main dam—is shown in cross section in an accompanying illustration. Its design was characterised by considerable investigations of the problems of soil mechanics presented by the predominance of clay. It was decided that, at the time, insufficient evidence was available to justify the use of clay for building the main bank, which would contain a large volume of material placed in a relatively short time.

There are, however, three subsidiary dams. Two of them separate sludge lagoons from the main reservoir, and the third limits the extent of the reservoir at its upstream end. These three dams are of homogeneous rolled clay fill, taken from borrow pits nearby. Construction of a homogeneous clay fill dam is unusual, and the upstream dam at Hanningfield has had pore water pressure gauges built into it to record the pore pressure history of the structure.

A similar homogeneous clay dam was built at Foxcote in Buckinghamshire, at about the same time as this dam, and in The Engineer of November 2, 1956, we explained the problem in soil mechanics which such construction involves. Since the two dams are very similar, no further description of the clay dam at Hanningfield will be given here, except to note that heavy Euclid plant was used to compact the clay. Slightly negative pore pressures have been recorded up to the present, we understand, in the Hanningfield clay dam.

The small catchment draining naturally to the reservoir site flows into a subsidiary reservoir on the upstream side of the clay dam, and is pumped into the main reservoir by plant installed in a small pumping station (pumping station No. 4), which is controlled remotely from the main purification works.

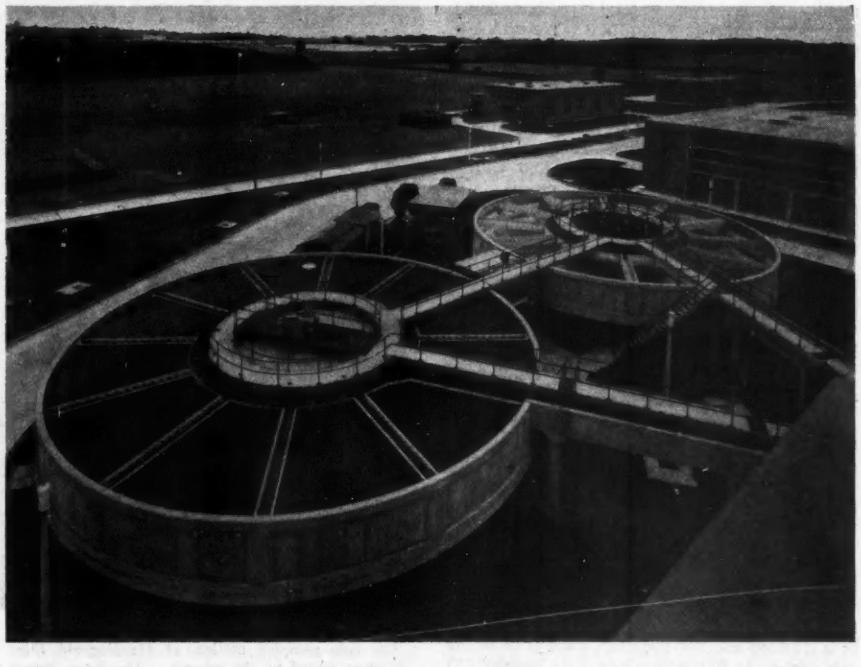
Turning now to the main embankment, it will be recalled that owing to its size and speed of construction clay could not be used for the filling material on either side of the core. Sandy gravel was therefore imported by road from neighbouring pits, the average haul being about 8 miles. A fleet of lorries brought in the large volume of material needed in about three years. The cross section of the dam shows a structure of conventional form, with a berm on the downstream side; this widening out serves to give an acceptable distribution of pressure on the underlying clay and also carries a road diversion.

The 48in aqueduct from Langford debouches into the reservoir at the right bank end of the main dam. There is a spillway and draw-off tower close to the left bank, but to ensure circulation of water in the reservoir it is intended that a second draw-off tower built about halfway up the reservoir on the left bank side shall be generally used. Both draw-off structures have outlets at three levels, and the 48in pipe from the upstream one, which is buried underneath the reservoir, passes through the second tower, where control of both may be effected. Circulation has also been improved by regrading a shallow area in the centre of the dam, raising part of it almost to crest level, with steep slopes. The left bank of the reservoir has also been regraded, balancing cut and fill and constructing a steep concrete-faced bank. Growth of vegetation is controlled and the quality of the water improved by avoiding large expanses of shallows by these measures.

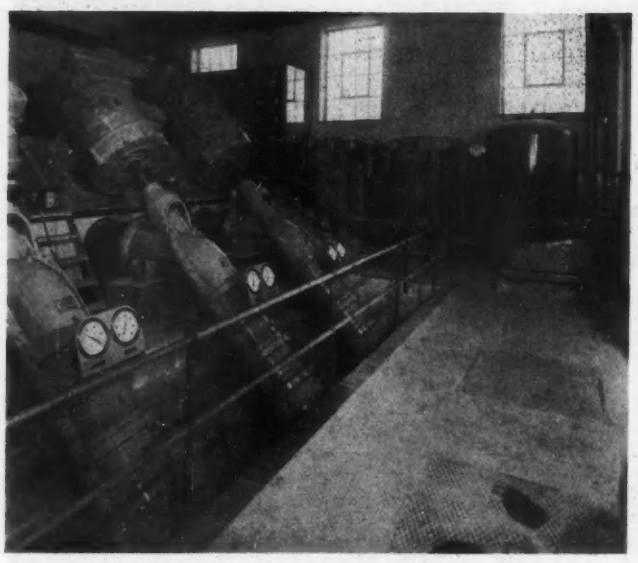
The draw-off tower at the main embankment incorporates a scour pipe and needle valve, and two short lengths of spillway built between the tower and the embankment; any spillway discharge falls to a central outlet, and passes to a stilling bay and thence to the Sandon brook. Since the reservoir is filled largely by pumping, spillage losses would be costly, and these two lengths of spillway are sheltered from direct wave action by the draw-off tower.

Intermediate Pumping Station

Water drawn from the reservoir is pumped to a supply chamber which gives a constant head for the flow to pass by gravity through the treatment works. The pumping station, which carries out this duty (No. 2 pumping station) is illustrated overleaf; it is characterised by axial-flow pumps, since the delivery head will vary between 5ft and 40ft, depending on the reservoir level. The pump speed may be varied between 470 and 1072 r.p.m. with power consumption correspondingly from 13 to 130 b.h.p. The variable-speed motors take power from the switchboard of the main pumping station (No. 3), which pumps treated water to supply. The No. 2 station is normally controlled from the control room in the treatment



Two of the four "Accelators." Treated water can be seen cascading into the launders in the foreground



Variable-speed axial-flow pumps, which operate over a head range of 5ft to 40ft, according to reservoir level, at pumping station No. 2

works ; one of the four pumps installed is a stand-by machine, the maximum output of the remaining three being 27 m.g.d.

Treatment Works

The treatment plant at Hanningfield comprises, in outline, the following stages : softening and clarification in a battery of four large 'Accelators" ; pH control following softening by the addition of CO_2, for which a contact tank is provided ; rapid-gravity filtration ; and finally addition of chlorine in a combined balancing reservoir and contact tank, prior to pumping into supply. The treatment plant buildings include a chemical house, which incorporates a control room and laboratory, and a boiler house partly for space heating, but also with CO_2 boilers installed. There is also a sludge recovery installation. Control of the treatment processes is centralised, principally on the panels in the control room in the chemical building.

Water Softening.—The legislation empowering construction of the scheme—the Hanningfield Water Order, 1950—calls for water with a total hardness not exceeding 150 parts per million. Prolonged storage in the reservoir, plus the small direct upland flow, will improve the bacterial quality of the river water, it is considered, and reduce temporary hardness. Nevertheless, softening treatment is needed.

The flow of water from the supply chamber gravitates through a 45in aqueduct and is metered by a 36in venturi and controlled by a butterfly valve as it passes to the "Accelators." There are four "Accelators," each of 250,000 gallons content, 65ft in diameter and with a water depth of 19ft, and their capacity is stated to be sufficient to meet the ultimate output of the works. They operate with upward flow and a sludge blanket in the following manner.

Raw water enters a central chamber at the base of the tank—the primary zone—from a distributing culvert round its circumference. Chemical additives are introduced here, too, and the circulating mass of precipitate thus formed is drawn upwards through a motor-driven impeller at the centre of the tank, to the secondary zone immediately above. It then flows over a circular weir to the slurry zone, round the outer part of the tank, where separation takes place. Clarified water rises into radial launders and flows into an annular collecting channel. Sludge collects in hoppers at the base of the slurry zone and is drawn off at intervals, when it flows by gravity to the sludge pump house. Some recirculation takes place from the slurry zone through the baffles in the tank, back to the primary zone.

Chemicals are fed to the "Accelators" from the adjoining chemical building. For softening, lime is added and also soda ash, since at times the non-carbonate hardness alone may exceed 150 parts per million. The chemicals are stored in concrete bunkers and are dispensed direct therefrom by dry feed machines. After mixing with water they are supplied to the "Accelators" through dosing gear.

The softening process is supplemented by coagulation with colloidal silica, produced by the partial neutralisation of the alkali in sodium silicate by sodium bicarbonate and applied to each pair of "Accelators." The use of this coagulant was selected as the result of experiments with a pilot plant made with water from the Abberton reservoir, which is similar in character to that anticipated at Hanningfield. It was thought, however, that certain conditions of the raw water might arise in which coagulation with colloidal silica might require to be supplemented, or even occasionally supplanted, by alumina. The alumina may be applied direct to the whole of the raw flow or to individual "Accelators."

The water may also be treated with chalk and activated carbon to correct respectively the possible carry-over of the finest algal forms at times of minimum softening precipitate, and occurrence of taste and odours from this or any other source should they appear. Chalk is applied along with the lime and carbon at the entrance to the contact tank.

Contact Tank.—The contact tank receives the softened and clarified water from the "Accelators" and is provided for the purpose of removing excess alkalinity—measured by pH meters—by the injection of carbon dioxide through tubular bubblers. The experimental work with colloidal silica indicated that optimum results with this process would be obtained around pH 10·0. This will therefore be the usual pH at which softening is carried out, the carbon dioxide being used to bring the pH down to about 8·0 for distribution and to prevent after-precipitation of chalk.

Carbon dioxide is produced by the combustion of metallurgical coke in automatically fired boilers, waste heat from the circulating water of the boilers being used to assist in lime slaking and to provide hot water for the laboratory. The whole of the gas producing plant is housed in the boiler house together with two oil-fired boilers for space heating.

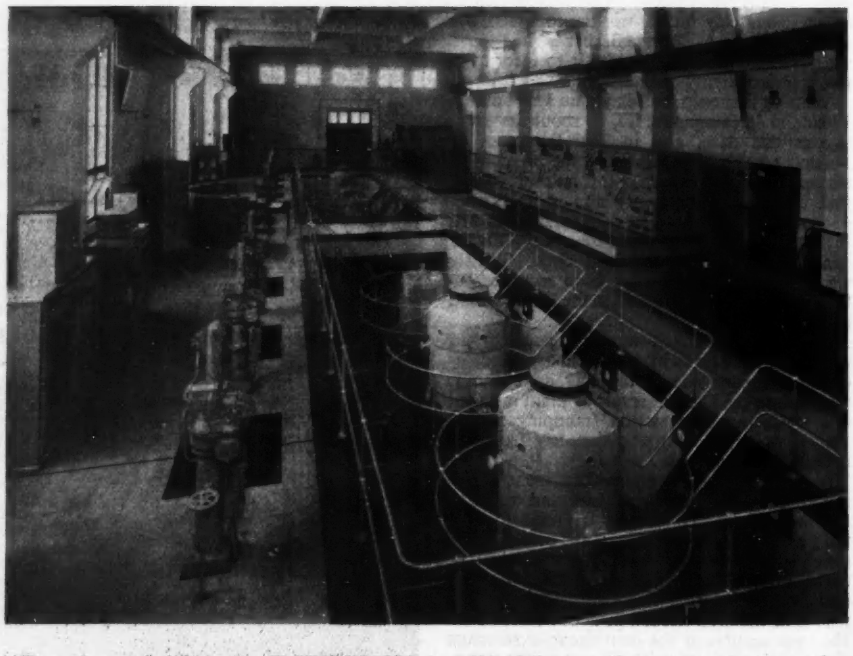
Rapid Gravity Filters.—Eight rapid gravity filters have been constructed for first-stage operation of the scheme, and they have a capacity of about 12 m.g.d. Their total area is 6912 square feet, and the rate of filtration 72 gallons per square foot per hour ; ultimately the installation will be doubled. It was considered that completely automatic control was not advantageous. The various operations involved in washing a filter are controlled from the filter control cabinet situated directly in front of each filter. The control cabinet also provides a visual indication and chart record of the normal working of each filter, the rate of flow and the loss of head condition as the filter becomes due for washing. The upward flow when washing a filter is about 7000 g.p.m. The washing water is drawn off through siphons at the sides of the filter, which assist the cleaning process.

Filtered Water Reservoir.—A 27in diameter pipe leads from the rapid gravity filters through a gauge house to the combined contact tank and filtered water reservoir. This tank is in two sections, each of 1 m.g.d. capacity. Automatic apparatus for controlling chlorination, sampling pumps and level indicators are installed in the gauge house.

Sludge Recovery Pump House.—Sludge from the "Accelators"—mainly chalk slurry—flows by gravity to two concrete tanks next to the sludge pump house. Here, two 40 h.p. pumps, which are automatically controlled according to the tank level, pump the sludge to the two lagoons on the left bank side of the reservoir, through a 12in main, which is about 2 miles in length. The capacity of the two lagoons is sufficient for eighty or 100 years' operation of the scheme ; the clear water flows through culverts in the cut-off dams, back into the main reservoir.

Pumping Station

The final operation at Hanningfield—that of pumping purified water into the supply mains—is effected in the scheme's pumping station No. 3, where the pumps are grouped according to the requirements of the two water companies. Three centrifugal pumps serve each company, and a



The main pumping station at Hanningfield (No. 3), which delivers purified water to the two supply systems served by the scheme. The three larger pumps will each deliver a maximum of 4·08 m.g.d. and the three smaller ones 3·6 m.g.d.

fourth pump for each is to be installed later on. The principal data for these pumps are : for the Southend company, each pump of 2 to 3·6 m.g.d. capacity, 45 to 115 b.h.p., head 80ft to 120ft, and operating speed 800 to 1120 r.p.m.; corresponding figures for the South Essex pumps are 2·5 to 4·08 m.g.d., 110 to 210 b.h.p., 164ft to 194ft, and 950 to 1200 r.p.m.

Power for operating the pump motors is drawn from the grid from a substation near the chemical house. The main distribution switchgear for the whole works is situated in the pumping station. Two 750kVA transformers serve pumping station No. 3, and the treatment plant generally, and two 250kVA transformers serve the No. 2 station. Two 550kVA diesel-alternator sets are to be installed for peak load reduction and in case of failure of the grid supply.

Construction

Apart from the major task of constructing the main embankment, constructional work has been on a large scale, involving particularly a great deal of pipelaying and of reinforced concrete work. Cathodic protection has been used as an additional protection for the pipelines, and the whole of the main treatment area has been made anodic. Concreting jobs have included a vast area of lining slabs, on the water slopes of the embankments and along the regraded shore line of the reservoir. Structural reinforced concrete included the covered reservoirs for purified water, and some intricate work in forming the various chambers and weirs of the four large "Accelators." The outer wall of each "Accelator" tank was cast *in situ*, but much of the interior work was precast.

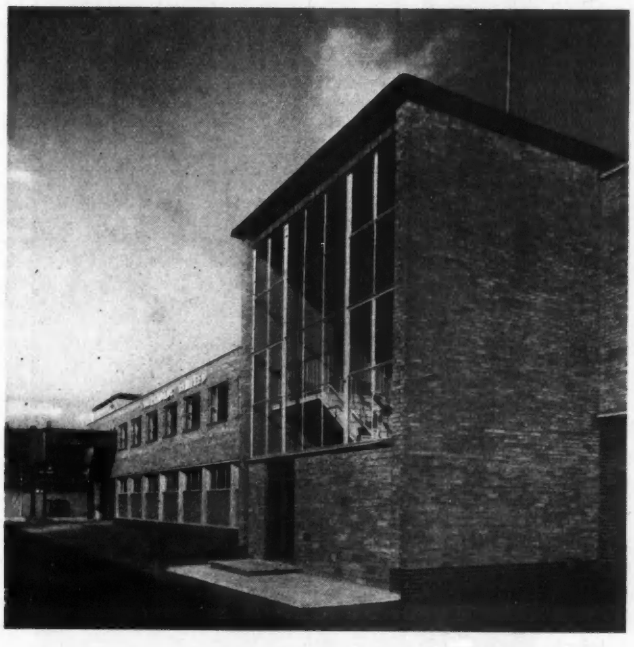
Two firms of consulting engineers have been jointly responsible to the Hanningfield Water Joint Managing Committee, for the design and execution of the works, namely, Messrs. Binnie, Deacon and Gourley, and Messrs. T. and C. Hawksley. The main contractor for the civil engineering works was W. and C. French, Ltd., the contractor for treatment works equipment being the Paterson Engineering Company, Ltd. Supply of steel pipes, cast iron pipes and valves was the responsibility of Stewarts and Lloyds, Ltd., Stanton Ironworks Company, Ltd., and Glenfield and Kennedy, Ltd., respectively.

The main contractors for pumping machinery were (*a*) at Langford, Sulzer Brothers (London), Ltd.; (*b*) stations Nos. 2 and 4, at Hanningfield, Vickers-Armstrongs, Ltd.; (*c*) the main pumping station (No. 3), at Hanningfield, The Harland Engineering Company, Ltd. The sub-contractor for pump motors was Laurence Scott and Electromotors, Ltd., in each case. Other electrical installations, at Hanningfield and Langford respectively, were done by Crompton Parkinson, Ltd., and the Brush Electrical Engineering Company, Ltd. Messrs. Heap and Digby were the electrical consultants.

The chief engineers of the Southend Waterworks Company and the South Essex Waterworks Company have also been closely concerned with the Hanningfield scheme. The cost of the works completed so far (i.e. the first stage) has been over £5,000,000.

Textile Development Plant at Rochdale

A new textile development unit has been opened recently by Courtaulds, Ltd., at Rochdale, and the building, of which we show the main entrance, houses a wide range of spinning, processing, knitting and weaving machinery. The unit will be engaged on research into the production of new and modified fibres and the development of production techniques so that the company will continue to improve the machinery for and the product development in staple fibre manipulation.



LAST week there was officially opened at Arrow Mill, Rochdale, a new building, which is the quarters of the textile development unit of Courtaulds, Ltd., a unit which was formed some twenty-four years ago at Flint, in North Wales. Since 1934 the experimental machines have been housed in the basement of the Arrow Mill, but the worsted experimental machinery was transferred to the newly acquired Westcroft Mill in 1937. Over the years and particularly since the war other equipment has been added to encourage the development of staple fibres in certain industries and the production of development cloths. Courtaulds, Ltd., has pioneered the use of man-made fibres and as an ancillary has actively supported and encouraged the development of various research associations in the full realisation that industrial progress is largely dependent upon such work. The company has its own particular interest in this field and the development unit is only one of many facilities which are engaged in the expansion, through research, of the company's products. A staff expert in the various techniques and production "know how" of the many diverse and complicated processes operate the range of equipment installed. Thus the unit provides the means to expedite the further progress of man-made staple fibres.

The scheme to expand the facilities of the Textile Development Unit, by housing it in a new building, was formulated some three years ago and work began in May, 1955. As completed, the building provides a floor area of 54,000 square feet in the main textile development shed, with a further 24,500 square feet for loading bays and stores, and 6000 square feet for laboratories and office accommodation, arranged on two levels. The whole of the building is steel framed and largely clad with brickwork, of which two contrasting tones are used for the main entrance and principal façade. In the main shed there are five 49ft bays having a height of 14ft to the underside of the roof trusses and a double glazed and insulated asbestos roof. The floor in the shed is of reinforced concrete cast *in situ* and covered with maple strip, while elsewhere the floors are of precast concrete covered with thermoplastic tiles.

To maintain the temperature and the humidity conditions required for the operations in the main shed the Andrew Machine Construction Company, Ltd., and Hall and Kay, Ltd., have provided a plant which is electronically controlled by the Honeywell-Brown automatic system. The day conditions required are normally 70 deg. Fah. dry bulb and 55 per cent relative humidity, while the night temperature is maintained at 65 deg. Fah., and the equipment consists of a spray chamber, two centrifugal fans with backward curved blade impellers and two centrifugal pumps, both fans and pumps being arranged for automatic starting. Shutters automatically control the amount of fresh and recirculated air, the quantity of the latter depending upon the amount of heat required for humidification. A gauge screen, which acts as a preliminary filter and is designed to catch any "fly" in the return air, encloses the fresh and return air mixing space and afterwards the air passes through a blanket filter, where the "smog" is removed. After passing through the spray chamber the air, containing a predetermined amount of moisture, is circulated through five ducts. The ducts are at truss level and are fitted with louvres, the total amount of air supplied by one fan being 49,000 cubic feet per minute, which is increased to 75,000 cubic feet per minute with both fans running. When starting from cold steam injection is used in the air washer sump in order to attain quickly the humidity required, the whole being regulated, together with the fresh air and return air shutters, by the dewpoint control. In addition to the dewpoint and heater controls, the electronic automatic control system includes a high and low limit control in the shed, which regulates the working of the fans and the steam valves. The low limit brings in No. 1 fan and opens the steam valves, while the high limit control brings into operation No. 2 fan. A separate air conditioning unit looks after the laboratory.

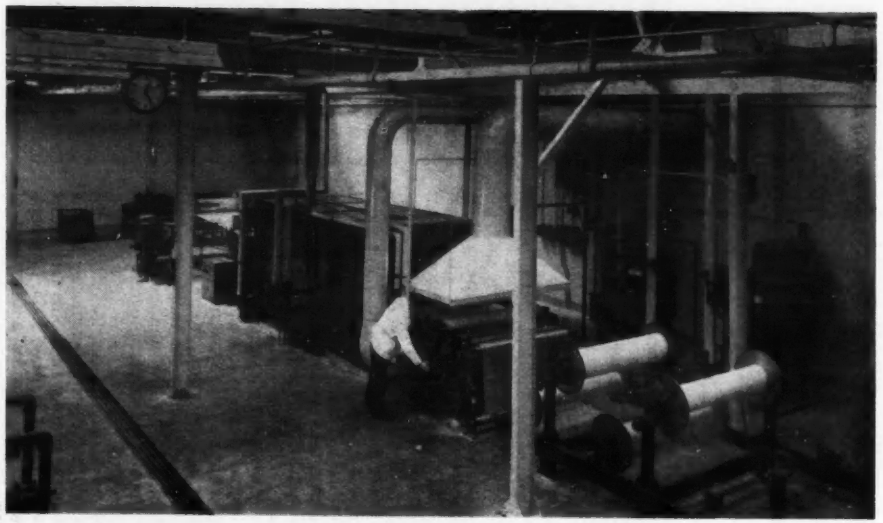
Steam is supplied from the Arrow Mill boiler house at 150 lb per square inch gauge and reduced to 50 lb per square inch gauge. Electrical supplies come from a 415V switchboard in the Arrow Mill and there is a 110V supply for hand tools and a 400V five-wire three-phase supply with a 12V pilot current for the semi-portable machines. Fluorescent lighting giving an intensity of 20 lumens per square foot is provided.

The expansion of the unit by the addition of new machines has been noted already and the present equipment includes a sizing section, weaving and knitting sections to cater for the demands of fabric development, and sections concerned with woollen spinning, tufted carpet production, flax and jute, and cotton spinning,

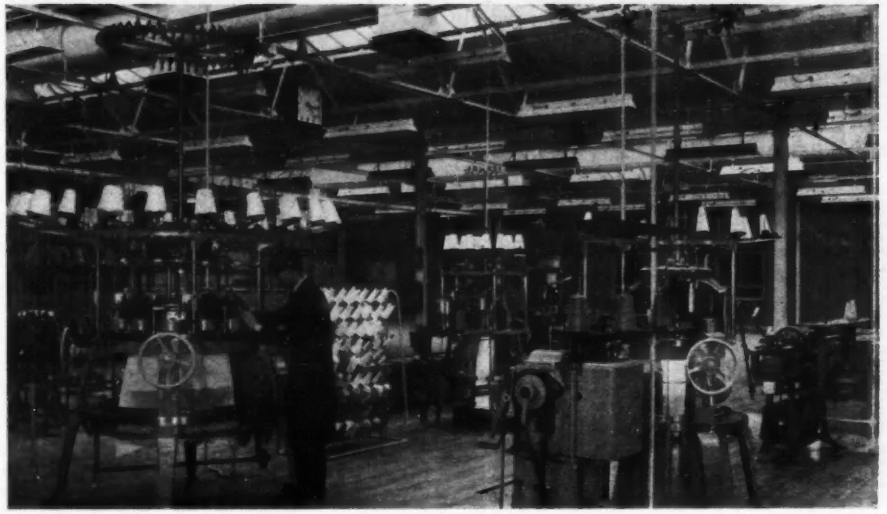
TEXTILE DEVELOPMENT PLANT AT ROCHDALE

Cotton machinery section

Flax, jute and worsted machines for processing long staple fibres



Sizing section



Knitting machines for the evaluation of spun yarns

and laboratories, some of which we illustrate.

The cotton spinning section is concerned with the development of new blends of yarns and assisting the laboratory in the evaluation of new fibres and also sampling work. Both American and British machines are available, the former consisting of a set of "Saco-Lowell" machines for processing cotton and man-made fibre and also a line of the "Whitin" spinning system, consisting of a "Roto-Rolo" draw frame, a Quick-Set roving frame and a "Superflex" ring spinning frame. This system spins the longer synthetic fibre and wool blends and acrylic slivers produced by the "Turbo-Stapler" which directly converts continuous tow to sliver. A wide range of fibres, deniers and staple lengths can be processed from bale to spun yarn in the section which opens with a Platt hopper opener and finisher scutcher to produce lap. Conversion from lap to sliver is by Platt revolving flat cards, where remaining impurities are removed, Saco-Lowell roller card or the Tatham carpet staple card. There is a traditional processing line of short length frames and another system consisting of two Platt draw frames, a high draft intermediate, thus cutting out slubbing and one head of drawing, followed by Tweedales and Smalley ring spinning and doubling frames. The Saco-Lowell line includes two draw frames, a roving frame and a Gwaltney spinning frame.

Yarn is prepared for processing within the unit, the yarn for weaving being wound direct to a back beam for sizing or on to a weaver's beam when of heavier gauge. The machinery is suitable for warp and weft preparation, and there are ring doublers, a doubling frame for carpet yarns, and a cone and cheese winder. Other items of equipment include a machine for transferring spun package to hank for dyeing purposes, a beaming frame having a capacity for 612 creels and a sectional warping mill. Warp sizing is carried out in a separate department and the principal piece of equipment is a machine, supplied by Joseph Hibbert and Co., Ltd. This is fitted with a Shirley automatic size box and a moist air drying chamber and can treat a variety of spun yarns both for internal and external use, while being available for the assessment of selected size mixtures. In the machine the ends from a number of back beams are brought together at the size box, after which they pass through squeeze rollers to remove the surplus size and assist in the impregnation of the yarn. The yarn now passes through a drying chamber where steam heated air is blown through the yarn, to remove the moisture, and exhausted to atmosphere. The sized yarn emerges from the dryer as a sheet and is passed over and between dividing rods which separate the threads into the original number of ends which are then wound on to a weaver's beam. Electronic equipment controls the amount of moisture and the air supply and the beam tension. The sizes used are such that they can be removed easily and so avoid problems in weaving and dyeing such as residual starch being left in the cloth. A Shirley single thread sizing machine is available for producing small sample warps.

A wide variety of looms, including a Northrop automatic silk and rayon loom, make for an extremely flexible weaving section, consisting mainly of dobbies with circular or drop boxes, Dobcross Jacquard machines having a varying number of picks per minute. The whole facilitates the development of new cloths using yarns spun on any system. Nearby is a tufted carpet machine for the assessment of fibre and yarn in tufted carpets, and for exploring the possibilities of blending coloured staples as well as a range of deniers in different materials as related to carpet quality. The 34in cut pile machine has 180 needles and is complete with latex applicator and ancillary equipment for cropping.

The machines in the woollen section cover the operations of blending, carding and spinning yarns from the finest to the coarsest skeins. In the blending room is an opening and blending machine, and in the main shed is a Tatham carpet set consisting of a hopper feed and automatic weigher, a two-part scribbler, centre draw and Scotch feed to a single-part carder. A six-tier tape condenser produces slubbing for coarse work, while for fine work there is a Platt machine having a two-part carder and a four-tier condenser. Slubbing spools are spun on a Platt woollen ring frame or an Asa Lees woollen mule. There is also a condenser section.

In the flax and jute group are three sets of machinery consisting of flax and jute machines manufactured by James Mackie and Sons, Ltd., and worsted machinery built by Prince-Smith and Stells, Ltd., and all use pin control for drafting carded slivers. There are two cards, which can be used singly or together, available for the production of slivers. For flax there are four drawing frames of push-bar pattern, feeding either of two roving frames, depending upon the coarseness required, while spinning is carried out on a semi-automatic doffer flyer spinning frame and on a modified ring spinning frame for the finer counts. Two push-bar drawing frames handle the jute and from roving on the semi-automatic doffer flyer spinning frame are spun the finer counts, while the coarser yarns are spun from sliver on the flyer sliver spinning frame. Work in the section is directed to developing modifications of practice intended to improve the quality of yarn and fabric production and the latest development is the inclusion of worsted machinery. This includes two inter-sector gill boxes, one having a Raper auto leveller, with the object of improving the quality of the yarns when spun by improving the regularity of slivers. Rovings are spun on a "Megaflex" high draft ring spinning frame incorporating an apron drafting system.

A small but specialised knitting section evaluates high bulk and conventional yarns from any spinning system over the whole range of man-made staple fibres. There are five machines, including a Dubied hand flat Jacquard for patterned outerwear; another fully automatic machine having an electronic stopping device; two Mellor Bromley units, one producing jersey fabric and the other underwear in shaped body lengths, and a Komet sock machine.

Situated within the office block and working closely with the development unit at all stages of processing is the laboratory which consists of two sections. Mechanical and colorimetric testing equipment is available for the analysis of yarn and fabric samples and the identification of fibres. Part of the laboratory is available for chemical analysis, microscopical investigations and the determination of fibre length distributions, while a separate section is maintained at a standard temperature and humidity in order to carry out physical tests which are influenced by moisture variations. In the latter section is a Lea strength tester and an "Uster" instrument which automatically test records the strength of single thread. Fineness is measured in a meter in which air is passed through a plug of fibres, the rate of flow being proportional to the surface area of the fibres. Also in the laboratory are a "Microaire" unit, and a vibrascope and electronic equipment to aid in the investigation of yarn and sliver irregularities and yielding graphical records.

125th Anniversary of Sir W. H. Bailey and Co.

A CENTURY and a quarter ago, when he was seventeen years old, John Bailey began a clock-making business in a Salford cottage. The enterprise then begun is still prospering to-day, and, as if to mark the anniversary, a works extension has just been completed which will make it possible to double the production of valves. For John Bailey's interests did not set fast in 1832; he was soon making many other things than the turret clocks he started with, and gauges, testers and boiler fittings emerged from his simple workshop. Industry in his business was followed by industry in public affairs, and for twenty-five years John Bailey was a Salford councillor. His son, William Henry, served an apprenticeship to his father at a very early age. Before he was twenty he had invented or improved a number of devices. When he was twenty-seven his father died, and William took over the business. An active man, he was always interested in new ideas. This attitude led him to become one of the original promoters and directors of the Manchester Ship Canal Company and it was on board the first ship to pass through the canal that he received his knighthood from Queen Victoria. His company continued to make turret clocks all through the nineteenth century, but a catalogue of 300 items issued at the time of the Manchester Jubilee Exhibition in 1887 included such diverse specialities as loud-speaking telephones, alphabetical telegraphs, automatic wind recorders, fog bells and pedometers. At Sir William's death, in 1913, the works were employing more than 300 men. Alfred John Bailey then stepped into his father's shoes and became governing director of the firm on his return from service in the first world war. The company at that time claimed to make a greater variety of machines than any other in the world, and maintained this claim up to 1940. Alfred's brother, Frederick, became chairman and managing director in 1940, on the death of the former, and suffered a bitter blow when the Albion Works was completely destroyed by bombing in 1940. Within weeks of the disaster, however, fitting work was begun on the company's iron foundry at Patricroft, and by the time of Frederick's death in 1943 the enterprise was re-established.

To commemorate its 125th anniversary, the company has produced a sixty-page book which is intended to help engineers easily to specify valves for many industrial applications. The book is said to list the majority of normal valves used for air, water, steam or gas at the present time, and is indexed in English, Spanish, French, German and Afrikaans. The compilers have lightheartedly included some pages entitled "Interesting Products," in which illustrations are reprinted from much earlier catalogues. The traditional catholicity of the firm's interests is amusingly exemplified by such items as "Bailey and Fogarty's patent beer raiser and aerator, which works automatically by the water pressure, similar to Bailey's Patent Hydraulic Organ Blower," and "Bailey's Motophone," operated by bellows or exhaust to produce notes "blending together into a most beautiful and far-reaching sound that will not irritate the most sensitive person." Entitled *A Guide to Valve Practice*, the book is being distributed at home and overseas. It includes references to the firm's other products, including its hand and power-driven pumps, pressure gauge testers and—incongruously only to those unfamiliar with the Bailey tradition—turnstiles.

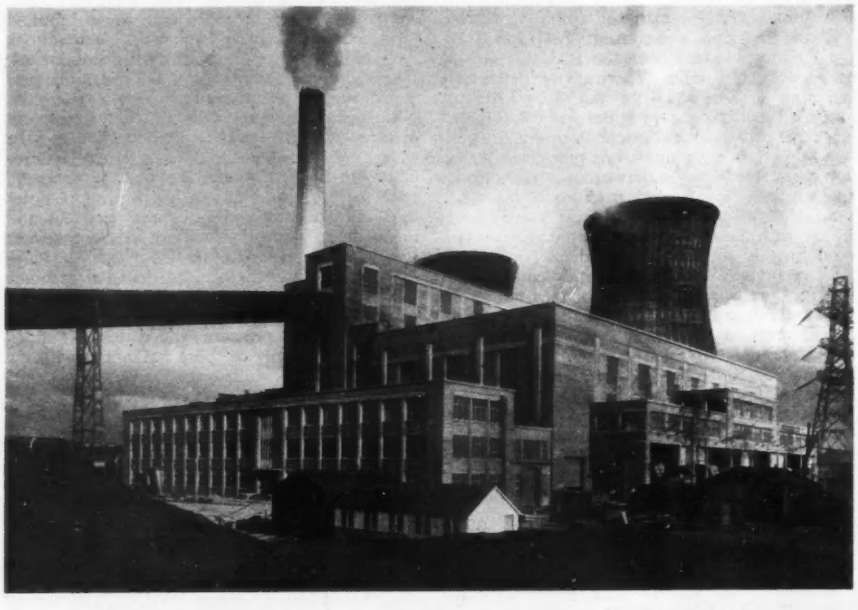
Residual Fuel Oil Improver

A NEW residual fuel oil improver, Amber Desulfurol (S.S.R.509), has been introduced by the Amber Chemical Company, Ltd., 11a, Albermarle Street, London, W.1, for the purpose of countering incomplete combustion and sulphur corrosion. The product has been developed in France and it is claimed that the addition of one part per thousand of Amber Desulfurol (S.S.R.509) to residual oil can reduce sulphur corrosion by between 50 to 75 per cent, increase the carbon dioxide content of flue gases, inhibit the formation of sludge, reduce smoke and soot, and reduce fuel consumption. It is also stated that the additive, which is a safe self-mixing liquid, also prevents the oxidation of sulphur dioxide into sulphur trioxide. In support of its contention the company quote a number of case histories in which trials carried out at a variety of industrial plants have revealed a considerable increase in carbon dioxide content as measured by the cold probe test. Tests were also carried out on board the "Bristol Queen," owned by P. and A. Campbell, Ltd., which has a double ended boiler fitted with the "Clyde" fuel system and three burners at each end and having a working pressure of 180 lb per square inch. Trials were made with and without the additive and the "Mono" carbon dioxide recorder, which was used as the test instrument, revealed that the addition of Amber Desulfurol (S.S.R.509) resulted in a considerable increase in the carbon dioxide content. A fuel saving of 7½ per cent was also measured. Fuel consumption trials were also carried out on the "Cardiff Queen," belonging to the same owners, having a double ended boiler with six burners at each end and fitted with "Wallsend" fuel system, and a saving of 9·5 per cent was recorded.

Wakefield "B" Power Station

A new power station is being opened to-day at Wakefield, Yorkshire. Designed for compactness and economy, the station makes use of low-grade fuel mined in the locality. Particular attention has been paid to boiler cleaning methods and safety in their application. The Construction Department of the Yorkshire Division of the C.E.A. has been responsible for the station. The installation consists of four 60MW turbo-generators taking steam at 900 lb per square inch and 900 deg. Fah. from four 550,000 lb per hour boilers.

TO be opened to-day, Friday, September 27, by the Mayor, Councillor M. Fitzpatrick, Wakefield "B" power station is situated on the south bank of the River Calder, between the river and the main Wakefield-Doncaster road. The first work on the site began in June, 1952. The civil, mechanical and electrical design of the station has been carried out by the Yorkshire Division of the C.E.A., and no consultants have been employed. The emphasis throughout has been on economy and compactness. It is claimed that the geometric volume of the station, per kW, is perhaps the smallest in the country and that the cost is less than £50 for each kW installed.



Wakefield "B" power station (seen here from the south-east) has been designed for compactness, and the cost per kilowatt installed is said to be less than £50. The two towers provide supplementary cooling when the temperature of the water returned to the River Calder is excessive

The present operating efficiency is about 29·6 per cent, and better still is hoped for in the future.

Site and Construction

The main site covers 55 acres, another 65 acres being available for ash disposal. The boiler and turbine house are founded on rock which crops out at the rear of the former and slopes down through the latter. The cooling water culverts have been fitted into this natural slope without need for excavation. The turbine house, electrical annexe and service block foundations are supported on piles driven down to the rock. The main building is 298ft square by 133ft high, while the three-storey accommodation building is 244ft by 42ft by 44ft high. The turbine house is 298ft by 110ft by 94ft high, and consists of a reinforced concrete frame with unstressed brick panels. The reinforced concrete barrel vaulted roof of the turbine house is 2¾in thick, the beams between the barrels being prestressed and post-tensioned on the Magnel-Blaton system. The roof was constructed in formwork supported from the floor on scaffolding. The main framework is partly exposed and has vertical lines formed by simple shapes in the shuttering. *In situ* reinforced concrete was used for the heads, sills and copings, so minimising the number of precast components. The turbine house is divided into nine bays. Construction was done simultaneously at different heights in five bays; three bays of the roof were cast during one month. The boiler house is a steel frame 264ft by 85ft by 133ft high, encased with *in situ* concrete tied to the steelwork. The internal walls of the station are of the white sand-lime variety to increase lighting and save decoration.

Steam Raising Plant

Locally mined open-cast coal is mixed with slurry, but there is no segregation of deliveries and no planned blending. The coal supply is at present almost entirely road-borne, though full rail facilities are provided. The fuel is discharged from contractors' lorries into two 25-ton underground hoppers, from which it passes through 150-ton per hour crushers to the conveyor feeding the boiler bunkers. From the bunkers the coal descends to the rotating table of one of the two feeders serving each 23-ton per hour pulverising mill. A pair of these mills serves each boiler. The pulverisers themselves are ball mills, and we understand that only one other power station in the country employs such mills. They are stated to have given great satisfaction, there having been no major maintenance on the first installed machine in its history of eighteen months. Raw coal and hot air enter each end of the mill, and pulverised fuel leaves at both ends in suspension; drying is thus effected before the coal enters the mill. Two exhausters equip each mill and supply four turbulent burners in the front wall of the furnace. The arrangement of the eight burners in each boiler is said to be such that even combustion is obtained with any combination of exhausters. The latter have a maximum capacity of 10,300 lb and a minimum of 3430 lb per hour.

There are four steam raising units, each with an output of 550,000 lb per hour at 950 lb per square inch and 925 deg. Fah. The single-drum water-tube boilers use natural circulation. The economiser from which water is supplied to the drum is of the plain tube type, with a heating surface of 13,568 square feet. The drum includes a system of horizontal centrifugal separators and transverse chevron driers which are intended to separate moisture from the saturated steam and thus to limit the amount of solid carried over to the superheater. The volume of the combustion chamber is 50,700 cubic feet and the heat release is given as 13,900 B.Th.U. per cubic foot per hour.

An improved method of cleaning has been devised that is said to be unique to this station. Aluminium scaffolding is assembled through holes in the water walls near the top of the combustion chamber. The sections are made up into a four-sided platform complete with hand railings, and can be raised or lowered through the whole height of the combustion chamber by the men themselves. Working from the bottom on built-up scaffolding is thus avoided and danger from falling slag is eliminated.

The gases from the combustion chamber pass through rows of 3½in diameter tubes to the superheater. The latter is self-draining and relies on convection only; it has a heating surface of 20,450 square feet. After leaving the superheater, the gases pass over the economiser and through two rotary air heaters to twin electrostatic precipitators, being then withdrawn by two induced draught fans (capacity 126,500 cubic feet per minute each) through a common flue to a single 350ft reinforced concrete chimney.

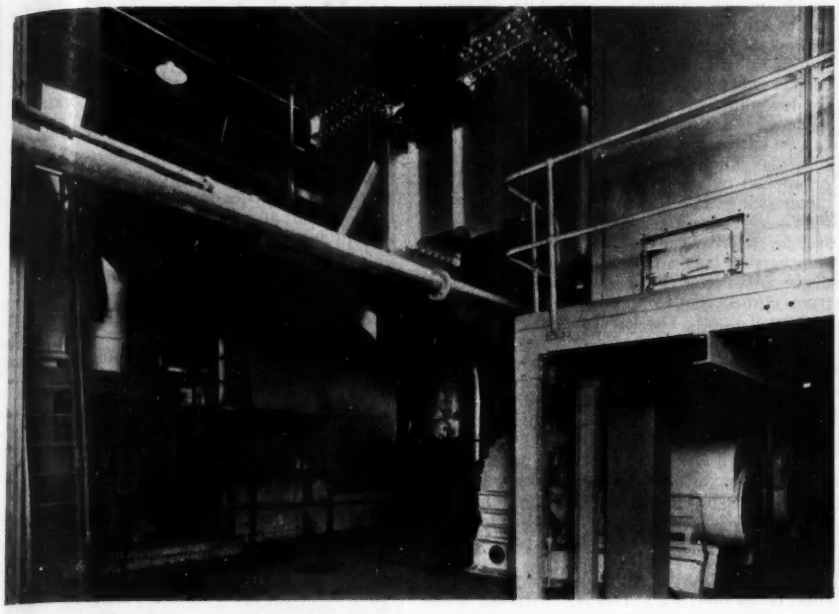
Four retractable and two non-retractable soot blowers are installed in both the furnace and the secondary superheater, as well as four retractable and four non-retractable blowers in the primary superheater. There are four locally controlled blowers in the air heater. Provision has been made to equip the economiser similarly if necessary. The two forced draught fans on each boiler have a capacity of 75,000 cubic feet per minute each.

The boiler automatic control system is pneumatic; essentially it comprises a master steam pressure regulator which balances the steam and air flows, and a furnace pressure regulator which keeps the suction constant in the combustion chamber.

Each boiler has an ash hopper. Hot, dry ash from the hoppers is quenched and then sluiced to the crushers by high-pressure water jets. The dust from the electrostatic precipitator hoppers, the economiser hoppers, the hopper in the chimney base and the receiver of the vacuum cleaning plant, is delivered by a second sluicing system to a sump under the crushers. Ash and dust from the sump are pumped by two 175 h.p. pumps to settling ponds, from which surplus water drains into the river. It is intended to pump the ash 2½ miles away eventually, and there is provision for the booster pumps that this will require.

Generating Plant

There are four 60MW turbo-generators designed for steam conditions of 900 lb per square inch and 900 deg. Fah. at the stop valve. The turbines have seventeen impulse stages in the high-pressure cylinder, fourteen impulse stages in the intermediate cylinder and one impulse and seven reaction stages in each half of the double-flow low-pressure cylinder. The guaranteed steam and heat consumption at 60MW are, respectively, 8·446 lb and 9224 B.Th.U. per kW hour. The three-cylinder casings form a unit which is anchored at the supporting feet at the low-pressure end. Steam is admitted through two emergency stop valves and two governing valves. The centrifugal governor is totally enclosed and driven from the turbine shaft. It controls a two-stage oil relay operating throttle valves. Each turbine exhausts into two three-pass condensers with a total cooling surface of 55,000 square feet, requiring 40,000 gallons of cooling water per minute at 65 deg. Fah. Condensate is withdrawn at 87 deg. Fah. into the feed system by two 100-per-cent-duty pumps driven by 158 h.p. motors. The condensate then goes through a drain cooler and two low-pressure feed heaters to a high level de-aerator heater, where make-up is introduced, thence through the feed pump to two high-pressure heaters and from them to the economisers. The drains are cas-



Ball mills pulverise the coal at Wakefield. No. 2 mill is shown here with its exhausters

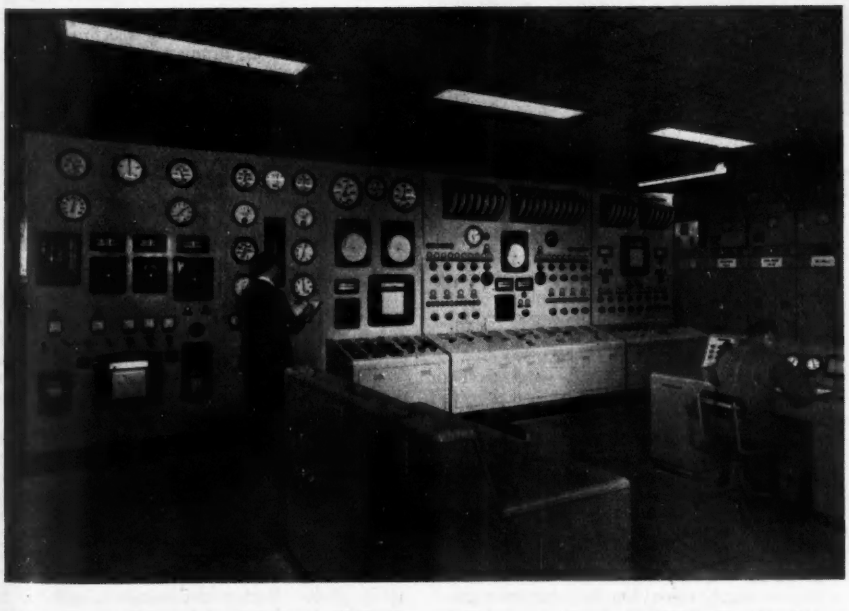
caded back through a cooler into the condenser. Each pair of boilers is supplied with water by three 100-per-cent-duty, six-stage centrifugal pumps. The little make-up required is drawn from the town mains and treated in a base-exchange softener, after which it is fed into two triple-effect evaporators, each dealing with 30,000 lb per hour. Cooling water for the condensers is pumped from the River Calder, to which it is returned after use. Supplementary cooling is obtained from two hyperbolic towers when river flow is low or atmospheric temperature high.

The turbines are directly coupled to the alternators, which are hydrogen cooled, the gas being cooled by river water. The alternators generate three-phase power at 11·8kV maintained within ±5 per cent. Each alternator is solidly coupled to a 72MVA, 11·8/141·6kV transformer housed in a bay of the main building. The conductors are "box angle" copper sections, flexible connections and 4000A through-bushings. Leads to the 6MVA, 11·8/3·45kV unit transformers are teed from these connections. The high tension connections of the main transformers consist of overhead lines to switchgear in an outdoor compound 450ft from the station. Power for auxiliary plant is normally from the unit transformers. For starting the plant there are two 10MVA, 132/3·45kV station transformers supplied from the 132kV switching station. They are coupled to two 3·3kV station boards which are interconnected with the 3·3kV unit boards.

Control

Two rooms, each containing control panels and desks for a pair of boilers and a pair of generating sets, are situated at operating floor level between the boiler house and the turbine room. One desk is occupied by the boiler operator and has two alarm facias for two boilers, as well as indicators showing the conditions in the firing ring main system, with telephone connection to the auxiliary plant attendants. The other desk is occupied by the turbine operator and contains alarm facias for two turbines and common services. The panels are arranged in three sections, "boiler," "master" and "turbine." The master panel carries the main instruments, the pointers of the latter standing at 12 o'clock under M.C.R. conditions.

Switchgear in the outdoor compound is operated from a main control room half-way along one wall of the turbine room. All four generating sets and the boilers are visible through two large plate glass windows, while similar windows in the outdoor wall give a good view of the switching station.



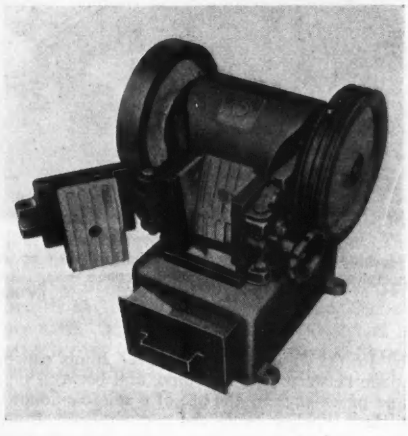
Each pair of boilers and generators is controlled from a single room at operating floor level. No. 3 panel is shown in this illustration, the "turbine" portion to the left and the "boiler" portion to the right. Under normal conditions all the pointers are approximately at 12 o'clock

Principal Contractors and Sub-Contractors

Demolition and clearance works, George Wimpey and Co., Ltd. Main civil engineering and river works, The Mitchell Construction Company, Ltd. Steel framework for boiler house and auxiliary bays, Dorman Long and Co., Ltd. Reinforced concrete frame and roof of turbine house, service block, &c., cooling tower shells, Holst and Co., Ltd. Main building and superstructure, M. J. Gleeson, Ltd. Coal handling plant and 132kV switching station foundations, M. Harrison and Co. (Leeds), Ltd. Chimney, Tileman and Co., Ltd. Railway sidings, Wm. Jones, Ltd. Railway bridge and abutments, S. Butler and Co., Ltd., and Holst and Co., Ltd. Coal handling plant, R. Dempster and Sons, Ltd. Tipplers, Strachan and Henshaw. Boilers, Foster-Wheeler, Ltd. Economisers, E. Green and Son, Ltd. Superheaters, The Superheater Company, Ltd. Air heaters, James Howden and Co., Ltd. Boiler mountings and high-pressure valves, Hopkinsons, Ltd. Soot blowers, Clyde Blowers, Ltd. Oil fuel equipment, Associated British Combustion, Ltd. Automatic boiler control and combined boiler and turbine control panels, James Gordon and Co., Ltd. Electrostatic precipitators, Sturtevant Engineering Company, Ltd. I.D. and F.D. fans, James Howden and Co., Ltd. Ash and dust handling plant, Babcock and Wilcox, Ltd. Turbo-alternators and feed heating plant, English Electric Company, Ltd. Condensers, de-aerators and auxiliary apparatus, Worthington-Simpson, Ltd. Boiler feed pumps, Mather and Platt, Ltd. Central evaporators and high-pressure pipework, Aiton and Co., Ltd. Low-pressure pipework, Brightside Heating and Engineering Company, Ltd. Low-pressure valves, J. Blakeborough and Sons, Ltd. Storage tanks, Horseley Bridge and Thos. Piggott, Ltd. Cooling towers, Davenport Engineering, Ltd. Circulating water screens, F. W. Bracket and Co., Ltd. Circulating water pumps, W. H. Allen, Sons and Co., Ltd. Chlorination plant, Wallace and Tiernan, Ltd. Turbine house crane, Sir Wm. Arrol and Co., Ltd. Semi-Goliath cranes, J. H. Carruthers and Co., Ltd. Painting, Baxter Bros. (1920), Ltd. Generator and station transformers, English Electric Company, Ltd. Generator-transformer 11·8kV connections, British Insulated Callender's Cables, Ltd. 132kV switchgear and connections, A. Reyrolle and Co., Ltd. 132kV overhead lines, Riley and Neate, Ltd. 132kV auxiliary and control cables, W. T. Henley's Telegraph Works Company, Ltd. 11kV unit and auxiliary transformers, Yorkshire Electric Transformer Company, Ltd. 415V switchgear, General Electric Company, Ltd. 11kV and low voltage main and auxiliary cables, Drake and Gorham (Manchester), Ltd. Lighting and heating, Green and Smith, Ltd. Fire-fighting installation, Mather and Platt, Ltd. Supervisory panel, internal telephones and staff location system, Standard Telephone and Cables, Ltd.

Laboratory Jaw Crushers

A NEW laboratory jaw crusher now being made in two sizes by Knapp and Bates, Ltd., 117, Africa House, Kingsway, London, W.C.2, has a frame fabricated from aluminium alloy in which



Jaw crusher for laboratory use. This machine is made in two models, each crushing down to $\frac{1}{16}$in product. It has an aluminium alloy frame fitted with manganese steel crushing surfaces

all the crushing and wearing surfaces are made of manganese steel. The eccentric drive for the crusher is situated at the top of the moving jaw where it is enclosed in a sealed oil bath. As can be seen in the accompanying illustration, the fixed jaw is fitted to a hinged door which opens outwards to give easy access for cleaning down after a sample has been crushed. A tightly fitting drawer into which the crushed product is discharged prevents loss of sample through escape of dust. A hand wheel control is used to set

the movable jaw stroke in accordance with the required product size.

The smallest model of these crushers has a jaw opening of 3½in by 2½in and requires a ½ to 1 h.p. drive at 450 r.p.m. It has a capacity of 250 lb of granite per hour, and can handle 1½in feed down to a $-\frac{3}{16}$in product. The larger machine takes a 2in product feed and has a jaw opening of 4½in by 3½in. It requires a 1½ to 2 h.p. drive at a speed of 400 r.p.m.

Both of the machines can be arranged for belt drive with fast-and-loose pulleys or for a motor drive with V-belts.

Automatic Pressure Butt Welding Machine for Steel Pipes

THE first commercial equipment to use a process developed by the Admiralty for high-quality butt welding of steel pipes is an automatic pressure butt welding machine made by Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester, 17. The new machine, illustrated here, is intended for workshop use and is designed to produce high-quality butt welds in low-carbon and low-alloy steel pipes in sizes from 3in (76mm) bore by $\frac{5}{16}$in (4·8mm) wall thickness up to 6½in (165mm) bore by ½in (12·7mm) wall thickness. Joints can be made between pipe and pipe, and between pipe and pipe flange by the use of a suitable adaptor plate. Welding times are comparatively short, from forty-five seconds up to four minutes, depending on the cross-sectional area of the pipe wall. The resulting weld has a smooth, compact upset section: for many applications it is unnecessary to remove either the internal or external upset. It is stated that the weld quality will readily meet test requirements for high-pressure pipelines.

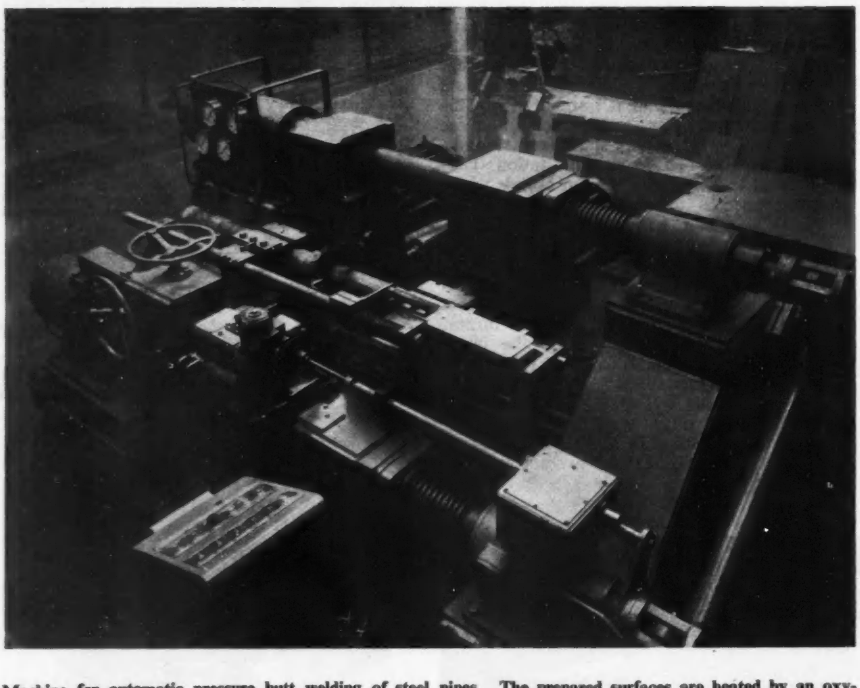
Essentially the process consists of bringing the prepared faces of the pipe ends together under a minor load and heating the joint by a multi-jet oxy-acetylene oscillating ring burner until a preset thermal expansion is reached. Then a higher load is then applied to return the pipe to its original length, when the final upset load operates to complete the weld. All sequences are controlled automatically by limit switches, which are also arranged to control the upset and to cut off the gas supply just before the completion of the weld. Post heat-treatment is required; it consists of normalising for low-carbon steel pipes and normalising and tempering for low-alloy steel pipes where air hardening tendencies are present. Straight normalising can be carried out in the machine.

A maximum clamping load of 100 tons can be applied by the two work clamps, which are direct-acting and hydraulically operated. The right-hand clamp assembly, supported on an anti-friction roller bearing, is attached to the main tension bars by means of split collars, whereby the distance between the clamps can be increased from 12in to 26in to accommodate such fittings as tube flanges. The left-hand clamp assembly is provided with horizontal and vertical adjustment to assist alignment of the tube ends with full clamping pressure applied. Movement of the tension bars is controlled by twin hydraulic cylinders, which can exert a maximum final upset load on the weld of 50 tons. Both the clamping cylinders and the upset cylinders are supplied from a self-contained hydraulic system, which is designed to give independent adjustment for each stage of the three-stage pressure cycle, that is, initial pressure, control pressure and upset pressure.

The water-cooled multi-jet oxy-acetylene burner ring is mounted on a roller carriage which carries the motor for oscillating the burner ring circumferentially and incorporates means of adjusting the burner ring to be concentric with the weld. It is connected mechanically to the moving clamp through a half-speed device so that the centre line of the burner ring is always kept on the centre line of the weld.

The operator's control desk, which is floor mounted, contains all the electrical controls required for the normal operation of the machine and those associated with preliminary tests when changing from one size of pipe to another. It also houses the special gas control and mixing unit and the gas flow indicators. The equipment requires a standard 380/440V, three-phase a.c. supply for the 10 h.p. pump motor and control gear, a clean cold water supply of approximately 1 gallon per minute (4½ litres per minute) and an adequate supply of oxygen and acetylene gas.

Machines of modified design to suit other ranges of tube size can be supplied to order by the same maker.

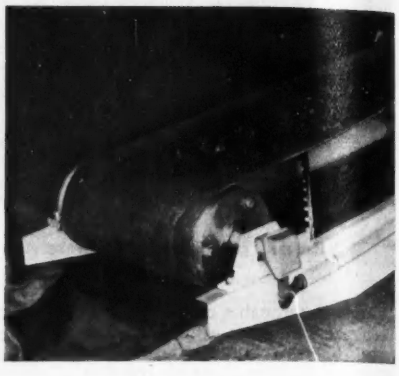


Machine for automatic pressure butt welding of steel pipes. The prepared surfaces are heated by an oxy-acetylene ring burner and welding pressure is applied in three stages, all sequences being controlled automatically by limit switches

Motorised Conveyor Drums

A MOTORISED drum for driving conveyors, elevators and other forms of mechanical handling plant is now being manufactured under the trade name "Thorite" by T. and T. Works, Ltd., Billesdon, Leicester, in co-operation with Richards Structural Steel Company, Ltd., Phœnix Ironworks, Leicester. These drums have built-in, totally enclosed driving motors, the power leads for which are brought out of a non-rotating support shaft at one end for connection to a convenient junction box, as shown in the accompanying illustration.

The non-rotating shaft is anchored in a bracket on one conveyor frame member, and it supports one end of the main drum casing through a ball bearing mounted end plate, the bore of which is fitted with seals to retain oil and prevent the ingress of dirt. The plate sealing the opposite end of the drum has a spigoted flange bolted on it and this spigot (rotating in a self-aligning roller bearing) supports the drum on the opposite side of the conveyor frame. The non-rotating shaft extends a short distance into the drum and at its inner end provides a rigid support for the motor frame as well as the centre bearing for one end of the armature shaft. The opposite end of this armature shaft rotates in roller bearings in a recess in the support flange assembly. The armature shaft is coupled to the support flange assembly through epicyclic reduction gearing, the reduction ratio of which can be selected in accordance with the required belt speed.



8in motorised drum driving a conveyor belt

The typical 8in driving drum illustrated can be supplied with a 1 h.p. to 1½ h.p. motor, and is available with four alternative gear ranges to give belt speeds of 25ft, 50ft, 100ft or 175ft per minute. We are informed by the firm that the range of motorised drums at present going into production extends from fractional to 15 h.p. at belt speeds from 25ft to 250ft per minute, but larger sizes and different speeds are at present the subject of design study.

Measurement of Compression in Diesel Engines

AN instrument is now available which is designed to measure the compression in multi-cylinder high and medium-speed diesel engines with the engines running at full speed. The manufacturer of the "Diestester" is the Dunedin Engineering Company, Ltd., 51, Beauchamp Place, London, S.W.3, and among the advantages claimed for the instrument are that its use eliminates personal judgment, it is simple with no complicated adjustments, it gives an accurate and steady reading, maximum compression continues to be indicated until released, and there is no piston or cylinder friction. To operate, all that has to be done is to remove the injector from the cylinder and insert the "Diestester" in its place. Each instrument is supplied with adaptors for 21mm and 24mm injector holder sizes, and it fits into a box measuring 13in by 8in by 2½in, the weight of the outfit being 10lb.

Industrial and Labour Notes

Economic Measures

In announcing the rise in the Bank rate to 7 per cent, on Thursday of last week, the Chancellor of the Exchequer stated that the Government was determined to maintain the internal and external value of the pound. Accordingly, the statement added, certain further steps in relation both to public and private spending had been decided upon. The object was to ensure that the supply of money and the consequent pressure of demand did not exceed the manpower and resources which were in fact available.

In the first place, the statement continued, the Government proposed to hold down the total of investment expenditure in the public sector, which had been planned to rise substantially during the next two years, within the level attained this year. It included the sum of investment by Government departments and local authorities and by the nationalised industries. Restrictions were also necessary in the private sector ; the supply of money in that sector must be controlled, and for that purpose, the Chancellor's statement intimated, the Government was prepared to take all necessary measures. Special considerations might arise in relation to certain export credits, but the Government's view was that the situation required that the average level of bank advances during the next twelve months should be held at the average level for the last twelve months.

In some comments on the measures announced by the Government, the British Employers' Confederation said that steadily mounting labour costs had been the major factor in forcing up prices and lessening this country's competitive power in world markets. Many employers would be hard hit and some people would lose their present jobs, but, the Confederation observed, if everybody acted sensibly there was no reason why there should be any widespread or lengthy unemployment. It ought to be possible, the statement went on, to get a closer balance between jobs and men instead of the situation in recent years of jobs chasing men, which had been debilitating for employers and workers alike and had discouraged and made difficult needed increases in efficiency.

Overseas Trade

The Board of Trade has stated that, at a monthly average of over £275 million in July and August, exports of United Kingdom goods were £4,500,000 a month less than in the first half of this year (excluding silver bullion repayments to the U.S.A.). In the two months, shipments of coal and coke declined, and exports of petroleum were marginally down in value although the quantity shipped exceeded the average in the first half of the year. Exports of metals also fell, by about 10½ per cent. Most of the main categories of engineering exports in July and August were little changed from the level of the first half-year, but the total for the group was increased by the inclusion of the aircraft carrier " Bonaventure " in the exports of ships and boats. Comparing exports in July and August with the corresponding months of 1956, the overall rise of 7 per cent included increases in all the main sectors except fuels.

The value of engineering exports in July and August, £114 million a month, was £10,000,000 higher than a year earlier, about half of the rise coming from " machinery other than electric." Aircraft engines, agricultural tractors, machine tools, and mining and oil well drilling equipment did particularly well. Electrical machinery and apparatus exports were 10 per cent higher than in the comparable months of 1956, the increase being in heavy electrical goods, especially in cables, the export of which to the U.S.A. was much higher. Exports of ships and boats in July and August were 28 per cent higher than a year earlier, though they would have been below last year's level but for the inclusion of the " Bonaventure " mentioned above. Exports of road vehicles averaged £28,000,000 a month in July and August, which was 13 per cent greater than a year earlier, when they were at a low ebb.

The Board of Trade has also stated that the favourable trend in the terms of trade, i.e., the ratio of import to export prices, continued in August, when the index (1954 = 100) moved from 97 to 94. The export price index rose by one point to 112. This was largely on account of the increase in the prices of engineering products, mainly electrical and non-electrical machinery, the index number for which rose to 114. The import price index number dropped by three points in August, from 108 to 105.

Coal Statistics

The National Coal Board's statistical statement for the second quarter of this year records an estimated deficit of £7,620,599. The loss on colliery operations during the quarter amounted to £3,724,599 (before charging interest), a sum which is reduced to £1,294,599 when account is taken of profits of £1,622,000 on opencast working and of £808,000 on the operations of the Board's ancillary undertakings. The amount which has to be provided for interest payable to the Minister of Power brings the deficit to the figure of £7,620,599.

During the quarter the saleable tonnage of coal from the Board's mines amounted to 53,343,310 tons, of which 50,304,798 tons were " disposable commercially." The proceeds for the quarter amounted to £207,771,136 and the total costs to £211,495,735. The biggest item in the latter figure was, of course, wages (including holiday pay and allowances in kind), which accounted for £126,466,868. During the quarter the average weekly earnings of all wage-earners, including the value of allowances in kind, were £15 5s., the average earnings of face workers being £17 3s. 6d. a week.

The World Bank Report

The twelfth annual report of the International Bank for Reconstruction and Development has been published this week. It deals with the year ended June 30 last, during which period the Bank made twenty loans, totalling the equivalent of 388 million dollars, in fifteen countries. Since it began its operations in 1946, the Bank has committed over 3100 million dollars in 170 loans to forty-five countries. Almost half the Bank's disbursements last year were made in currencies other than United States dollars.

The report says that the first post-war decade has been one of the most active periods of international investment of recent times, a consequence of which has been a large increase in the external debt of many of the Bank's member countries. From a survey of the subject which has been made recently it is estimated that the aggregate external long-term debt of fifty-two member countries had risen to the equivalent of 23,000 million dollars by 1955, or about twice the amount outstanding ten years earlier. But, the report adds, this increase in debt must be viewed in the perspective of the rapid post-war economic growth. In most countries this economic growth has not only made it possible for them to maintain service on debt now outstanding, but also provides a foundation for further productive investment.

Last year, the report goes on, the Bank continued to lend mainly for basic services that stimulate economic growth. A sum of 108 million dollars, representing more than 25 per cent of the year's lendings, was for the expansion of electric power services. Loans for sea, land and air transport totalled 55,000,000 dollars, and a similar amount was lent for agriculture. Various industrial projects received a total of 95,000,000 dollars, and the remainder of the year's lending was accounted for by 75,000,000 dollars of interim financing for the second seven-year plan in Iran.

Work Study on the Railways

The Western Region of British Railways has stated that, since the inauguration of its work study school at the beginning of last year, there has been a steady development of the use of work study techniques in many fields throughout the region.

During the twenty months of its existence the school has trained thirty-six senior work study assistants, together with 136 general work study assistants to work under the seniors. In addition, some 354 officers and other members of the staff have attended Appreciation Courses ranging from one week to one or two days' duration. The school now has its own team of lecturers drawn from the senior courses. Hitherto the emphasis in the school's activities has been upon the application of work study to practical operations, but it has now been decided to introduce specialist courses devoted to the study of office work in its various forms. The first of these courses, and the first of their kind on British Railways, started earlier this month at the school's Westbourne Terrace premises. Each course has been designed to extend over a period of eight weeks, during which time the trainees will receive comprehensive instruction in the investigation of the many aspects of office work, the lectures being interspersed with practical exercises and demonstrations. Use is being made of filmed material for training purposes and a feature of the course is the placing of trainees on practical assignments for three weeks whilst they are still under instruction. In this way students will get a first-hand experience of the problems that are likely to arise in the practical application of office methods work. The new courses have as the objective the production of trained office method investigators, who can apply the principles of scientific investigations and analysis to office work with a view to its simplification and improvement.

International Motor Show at Frankfurt

No. I

THE International Motor Show at Frankfurt which opened on Thursday, September 19, is the twenty-eighth German automobile exhibition and the fourth organised since the war. Unlike the Paris Salon and the London Motor Show, the German show, which comprises motor-cars and commercial vehicles, is staged at bi-annual intervals. The organisers, the Verband der Automobil Industrie, maintain that automobile engineering has now passed the phase of outstanding new developments and has settled down to a stage governed by steady, though less spectacular, detail improvements which would not justify the expense of annual exhibitions. By this decision the German show has actually gained technical interest without losing its attraction to the public and, to judge from the great number of foreign visitors, its importance as an international trade fair.

This year's exhibition is on an even grander scale than the 1955 show and must be acknowledged to be the largest automobile exhibition so far staged. The floor space of the exhibition halls has been further increased, now covering more than 18 acres, and about 6 acres of open-air parks are allotted to heavy vehicle demonstrations and to all sorts of equipment in actual operation. In view of the great number of exhibitors the distribution of floor space to individual firms has been generally curtailed; nevertheless the large German manufacturers like Daimler-Benz, Ford, Auto-Union, Volkswagen and Bosch still maintain their own exhibition halls, and fully utilise this opportunity of presenting their products with an air of efficient showmanship.

Apart from some thirty German firms, showing a great variety of motor-cars and commercial vehicles, there are fifty-seven foreign firms, among them all leading motor manufacturers of Europe and U.S.A., with a comprehensive display of thirty-four different types of cars and five of commercial vehicles. The British contingent, consisting of thirteen makes, is represented by the British Motor Corporation, Standard, and the Rootes Group; further, British Ford cars were on show in the exhibition hall of the German Ford Motor Company. The presence of so many foreign firms at the show is mainly a matter of prestige, for the actual imports of American, British and French cars are negligible and almost entirely limited to members of the Allied Forces stationed in Germany. Nevertheless, scheduled ahead of the Paris Salon and the London Motor Show, the German exhibition provides the first of the three international shop windows to be seen this autumn and gives the motor industry a splendid opportunity of demonstrating to buyers from all over the world the relative merits of its latest products.

The German motor show is of particular interest to the British visitor from the economic point of view, for in the last two or three years German motor manufacturers have proved to be the strongest competitors of the British industry in all markets outside the Commonwealth trade area. By the middle of last year German production had already surpassed British, and to-day Germany is not only the largest automobile producing country outside the U.S.A., but also the world's greatest exporter of motor-cars. This rather startling increase in productivity is clearly presented by Table I showing the German production and export figures for the first six months of this year, compared with those of the same period in 1955, i.e. the year of the last German motor show. The table also shows the corresponding figures of the British motor industry.

The German motor industry at present produces at the rate of about 4800 vehicles per day, about 14 per cent more than the British industry; the rate of exports to total production, amounting to about 47 per cent, is slightly lower than the British one of about 51 per cent. The main German export markets are the European countries without an automobile industry of their own (63 per cent) and America (22 per cent). On the American continent German export drive has lately been concentrating on U.S.A. It is reported that the Volkswagen at present accounts for about 40 per cent of all U.S.A. car imports and leads the French "Dauphine" and the British Ford cars. Increased sales in this important market are also expected from a recently signed agreement between Daimler-Benz and the Packard-Studebaker Corporation which gives the latter the sole right of selling Mercedes cars and goods vehicles in North America and to use certain manufacturing rights in their own manufacturing programme.

One might feel inclined to ask for concrete reasons which make German vehicles and, in particular, German motor-cars, so attractive to foreign customers. Is it, as the German constructors claim, their technical superiority, or, as many competitors allege, clever propaganda and high-pressure salesmanship? It is almost impossible to answer this question impartially; as far as the technical aspect is concerned, it is our (entirely subjective) opinion that much of the popularity of German cars is based on the flexibility of the German manufacturers who can offer vehicles of advanced design and a variety of technical innovations which seem to appeal to foreign customers. From the more economic point of view it appears that the present boom of the German motor industry is closely connected with the general prosperity of the country which is clearly expressed by the remarkable freedom from labour disputes and the stability of wages and prices. In the first six months of this year the prices of some cars have been reduced, while in other cases technical improvements and additional equipment made a material indirect contribution to a cut in prices. The price index for motor vehicles in West Germany at the end of December 1956 stood at 98 (1950=100), compared with a level considerably above 100 in the case of the majority of raw material and primary products.

German motor manufacturers, though aware of the risk that the home market might gradually approach the saturation point, are generally confident that, for some time to come, this prosperity will continue, and they are moderately optimistic with regard to the newly established European Common Market. They have invested considerable sums in modernising and expanding their plants and will undoubtedly try hard to intensify the export drive in accordance with their increased production capacity. Whether such efforts will have the desired effect is difficult to foretell; their success will mainly depend on the solution of such problems as export finance or, more generally speaking, on the development of the monetary situation where the present "currency distortion," caused by the strength of the D-Mark in foreign exchange markets, unless adequately re-adjusted, might adversely affect Germany's trade potential.

Turning from this general survey of the economic position of the German motor industry to the technical aspect of the Frankfurt exhibition we notice that the latest models of the medium-sized cars, though modified in minor details, do not show any startling or revolutionary changes in design. Such a development, of course, is to be expected in a period of full productivity when there is neither the technical necessity nor the sales incentive for any drastic change in design practice. Unorthodox in their constructional layout as many of the exhibits may appear to British visitors, there is no doubt that, with the exception of those built by the European associates of the big American parent companies, Ford and General Motors, they all conform more or less to the general standard now almost universally accepted on the continent. This applies particularly to small cars up to 1-litre cylinder capacity, all of which are characterised by such features as air-cooled or two-stroke engines, front-wheel drive or rear-engine mounting.

It is interesting to note that, since the last Frankfurt show in 1955, the number of miniature cars, i.e. those of about 500 c.c. cylinder capacity, at the exhibition stands as well as on German roads, has increased considerably. Table II presents the number of cars, arranged according to their cylinder capacity, produced in the first six months of this year compared with those built in the same period 1956. It will be seen that the number of small cars has increased in these last two years at a higher rate than that of the most popular car of the 1–2-litre class, while the number of cars of more than 2-litre cylinder capacity has dropped. The reason for the popularity of the "miniature car" is obvious; it is due to the general tendency of turning from the motor-cycle and motor-scooter in the sphere of everyday transport towards a small low-priced utility vehicle which offers full weather protection and adequate seating accommodation for at least two adults and a limited amount of luggage space (or alternatively, an emergency seat for children) together with such amenities as heating, wind-screen wipers and defrosters.

A few years ago it was considered rather doubtful whether such cars would prove sufficiently attractive in respect of speed, flexibility and passenger comfort, to create a noticeable demand. However, large scale production of well designed vehicles by manufacturers with adequate resources has proved without any doubt that there is a definite and growing market for these cars at home as well as abroad, in spite of the fact that the selling prices—per unit of weight—are up to 50 per cent higher than those of the cheapest of the more conventional small cars. At the 1955 Frankfurt motor show it was not easy to discern the general trend which the development of the German small car was likely to follow. To-day, two years later, there seems to be little doubt that the designers have clearly decided in favour of the independently sprung four-wheeler, having a wheelbase

TABLE I—*Production and Exports of Motor Vehicles for the First Six Months of* 1957 *Compared to* 1955

A. Germany (exports in 1957: 46·5 per cent of total production).

	Motor-cars		Per cent change	Commercial vehicles		Per cent change	Total		Per cent change
	1957	1955		1957	1955		1957	1955	
Production	467,380	360,622	+30·0	135,946	72,075	+88·0	603,346	432,697	+40·0
Exports	238,270	172,069	+38·0	43,486	30,295	+43·0	281,704	202,364	+39·0

B. Great Britain (exports in 1957: 50·5 per cent of total production).

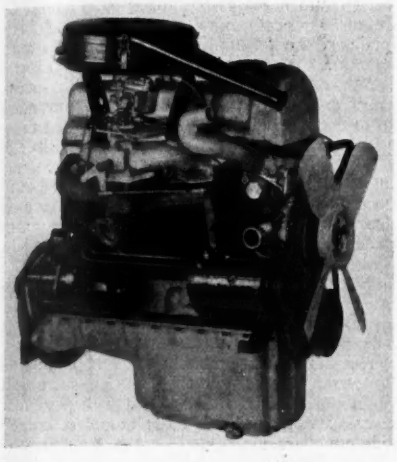
	Motor-cars		Per cent change	Commercial vehicles		Per cent change	Total		Per cent change
	1957	1955		1957	1955		1957	1955	
Production	388,572	460,740	−15·5	139,024	165,876	−16·0	527,596	626,611	−15·5
Exports	204,946	200,360	− 0·5	62,127	78,007	−20·5	267,073	278,367	−4·0

TABLE II—*Production of Motor-cars in Germany for the First Six Months of* 1957 *compared with* 1956.

	1957	1956	Per cent change
Motor-cars	467,380	432,967	+ 8·2
Up to 0·5-litre cylinder cap.	46,381	40,309	+15·0
From 0·5–1-litre cylinder cap.	47,329	51,784	− 8·5
From 1–2-litre cylinder cap.	345,840	305,778	+13·1
More than 2-litre cylinder cap.	27,767	34,096	−18·6

of 7ft to 8ft, and a dry weight of about 10 cwt, powered by a rear-mounted air-cooled engine of 15 h.p. to 20 h.p. There are, of course, still some divergences of opinion about such detail designs as suspension systems, drive arrangements, &c., but otherwise the principles of the general layout are pretty well defined. Most cars of this category surprise by the originality of their detail design, and offer an excellent opportunity to students of automobile engineering to examine some interesting examples of air-cooled engines and gearboxes.

As far as cars of more than 1-litre cylinder capacity are concerned, the design of cars and major components is more stabilised, and in this field development has mainly been concentrated



The Mercedes-Benz 1·9-litre engine has a chain-driven single overhead camshaft and a carburetter

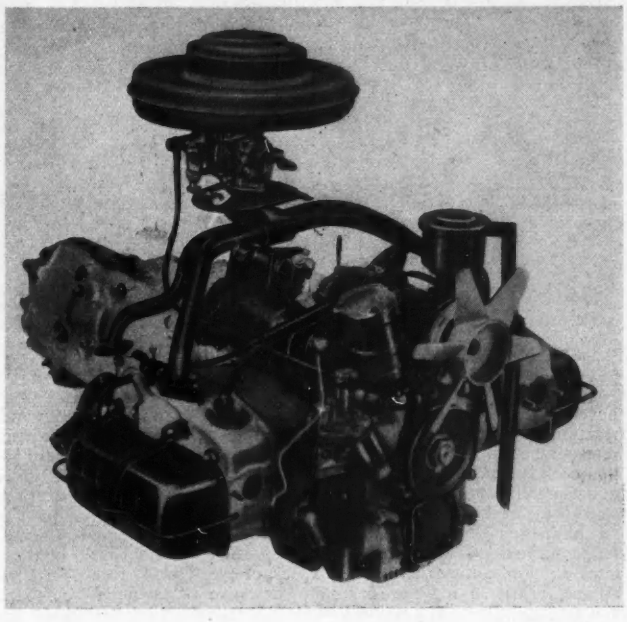
on improvements to styling and equipment, on refinements in engine design and, in conformity with the general European trend, on devices for facilitating the gear change.

When we turn to a survey of the various exhibits, lack of space dissuades us from mentioning German models which differ from those seen at recent international motor shows in minor details only and, further, from describing those foreign cars which are likely to appear at the coming London Motor Show.

Daimler-Benz, Germany's oldest and best known automobile factory, presents a complete range of its large manufacturing programme of Mercedes cars, commercial vehicles and diesel engines. In the car section public attention is focused on the new Model 180; the car is basically similar to the old Model 180, but the former 1·8-litre side-valve engine, after a life of 20 years, has been replaced by a slightly modified version of the 1·9-litre four-cylinder engine of the fast touring car, Model 190. The new engine, of 85mm bore and 83·6mm stroke, has a chain-driven overhead camshaft and, with a compression ratio of 6·8: 1 (compared to 7·5: 1 of the fast touring car engine), develops 65 h.p. at 4500 r.p.m. By the installation of the new more powerful engine—a step which has actually been overdue for some time—the Model 180 has gained in speed and flexibility. As the price has not been increased it can be expected that the car, the sales of which had dropped considerably in the last 12 months, will soon regain its former popularity.

The Mercedes types 219 and 220, both fitted with 2·2-litre six-cylinder overhead camshaft engines of similar design to the 1·9-litre four-cylinder, have remained unaltered, but they are now optionally available with the new Daimler-Benz "Hydrac" two-pedal control. This system comprises a hydraulic coupling and an additional single-dry-plate friction clutch with vacuum-operated withdrawal mechanism placed between the engine and a conventional fully synchronised four-speed gearbox. The hydraulic coupling serves to take up the drive from rest and, an at engine speed in excess of 1600 r.p.m., operates practically without slip. The friction clutch breaks the drive for the gear-change; its withdrawal linkage is connected to a vacuum servo-cylinder which is actuated by the depression in the inlet manifold. Pressure on the gear-change lever energises a solenoid, thus controlling valves to the vacuum chamber. To smooth out the re-engagement of the friction clutch after the gear change an electric contact is interposed between the rubber-mounted final drive casing and the frame; it is connected through a relay to the control valve of the clutch-operating servo unit and, being responsive to the torque reactions of the rear wheels, acts as an overriding control governing the clutch movement. (See figure overleaf.)

Another interesting detail of the "Hydrac" system is a roller-type free-wheel placed between the impeller shaft and the rotary pump-housing of the hydraulic coupling. It works in reverse of the normal sense of rotation, i.e. it permits the driving part of the coupling to over-run the driven part, but locks solid if the latter over-runs the driving part. The engine, therefore, can transmit its torque to the rear wheels only through the hydraulic circuit while, on torque reversal, the impeller is solidly locked through the free-wheel to the pump part of the coupling. This permits the driver to utilise the braking effect of the engine when descending a hill and to supplement the handbrake if the car is left stationary on a gradient.



The horizontally opposed, four-cylinder, four-stroke engine of the 1·1-litre "Goliath"

The biggest and probably the most representative German car is the type 300, the only Mercedes car of the standard range which still retains the X-shaped frame with deep oval tubes. The car is generally supplied with a Borg-Warner three-speed automatic transmission, but is optionally available with a conventional fully synchronised four-speed gearbox. Compared to the previous models the new type 300 has a longer wheelbase, and the roomy six-seater saloon body has an unusually large window area. The main mechanical alteration concerns the six-cylinder 3-litre engine which, like that of the types 300 S and 300 SL, is now fitted with petrol injection. The injection system, however, differs from that of those two engines and, instead of the former injection direct into the combustion chamber, injection is now made downstream into the individual branches of the inlet manifold, a short distance before their joint with the cylinder block. The multi-cylinder Bosch petrol injection pump with vacuum-controlled governor has been retained, and an elaborate additional control system adjusts the amount of fuel injected in relation to the cooling-water temperature and the pressure and temperature of the ambient air. The 3-litre engine with the new injection system develops 160 h.p. at 5400 r.p.m., compared to 175 h.p. (at the same speed and the same compression ratio of 8·55: 1) of the type 300 S engine with direct injection into the combustion chamber. Fuel injection can increase the output of a petrol engine by as much as 40 per cent and its economy by 10 to 15 per cent with considerable improvements in the obtainable torque characteristic. Owing to the high cost and the complexity of injection equipment it can be assumed that, for some time to come, this system will be restricted to expensive high-performance engines.

It is always interesting to visit, at international motor shows, the stand of Volkswagen-Werke, not so much in the expectation of seeing any

A ten-seat bus on the 1100 c.c. "Goliath" back-bone chassis

A car built by a motor-cycle manufacturer, the 600 c.c. N.S.U. "Prince"

novel design features, but in order to watch the reactions of the public and to find out from their remarks the reasons why this car, designed before the second world war and built with hardly any major modifications for the last ten years at a steadily increasing rate, has made such an impact on international markets. There are, of course, numerous critics who comment upon such intrinsic disadvantages of the car as lack of eye appeal, restricted luggage space, and excessive engine noise. The great majority of Volkswagen users, however, seem to be satisfied with the economy, the road-holding, and the general performance of the car under extreme climatic conditions. Nearly all comment favourably upon the cheap and easily available service and on the fixed-price maintenance.

The Volkswagen works, with a production last year of 345,000 cars and 60,000 commercial vehicles (about 52 per cent are being exported) are the greatest car producers outside the U.S.A. In Germany they clearly dominate the market in the most popular class of 1 to 2-litre cars, although their proportional share of new car registrations last year has dropped slightly to 32·3 per cent compared with 35·4 per cent in 1955.

At the exhibition the firm presents an impressive display showing all the different versions of the one and only basic model they produce. Contrary to the rumours, so frequently heard before the opening of previous motor shows, that Volkswagen would market an entirely new car, there is no major change in the general layout. This year's modifications are confined to minor details, the most obvious being a rear window of larger area, a slightly higher windscreen, narrower front pillars and a re-styled instrument panel. It appears that, as long as the current models are not meeting with any noticeable sales resistance, the manufacturers will continue to maintain their policy of evolutionary development ; it can be taken for granted, however, that they are well prepared to launch, at short notice, some advanced type should a drop in sales or, more probably, the European Common Market, necessitate such a step.

The second biggest German motor factory is the Adam Opel A.G., an associate of the American General Motors Corporation, with a production last year of 163,000 motor-cars and 44,000 commercial vehicles. The two car models made by Opel, the six-cylinder "Kapitän" and the four-cylinder "Olympia," were the first German cars built in integral construction, and, since their introduction in 1934, have undergone very few major changes in their general layout. The most popular type, the 1·5-litre four-cylinder Opel "Olympia Record," a model always distinguished by good styling, makes its appearance this year as a new two-door saloon of modern pleasing appearance and appears to be particularly designed to suit the present fashion of the U.S.A., in which market the Opel cars are being sold by the American parent company. The well proportioned "Olympia" with its wide wrapped round windscreen and its large rear window, is rather similar in appearance to the British Vauxhall "Victor" though, with less ornamentation, it is more restrained in its styling. Both cars also have some mechanical specifications in common, in particular the "over square" engine and the synchronised bottom ratio of the three-speed gearbox. The main mechanical modifications to the new "Olympia" compared to last year's model are a lower centre of gravity, a wider front track, improvements to the front suspension by adopting coil springs with a progressive characteristic and a revised layout of the steering geometry. With the improved road-holding and handling properties the new model can safely be expected to hold its place as the second best-selling car in Germany.

The German Ford-Werke of Cologne are presenting an entirely new 1·7-litre car, the "Taunus 17 M," in addition to their 1·2 and 1·5-litre "Taunus" models. The two latter are being continued with some modifications in styling, but they are now fitted with three-speed gearboxes having a synchronised bottom gear ratio. The new "Taunus M 17," which is being built as a two-door or as a four-door saloon and also a station wagon, in appearance as well as in its technical details has much in common with the British Ford "Consul" Mark II. Its wheelbase is 4½in longer and the track is 2in wider than those of the previous models, and, with an overall length of 14ft 8in, the new car offers a better passenger accommodation and greater riding comfort. The springing also has been improved by replacing the former conventional double-wishbone suspension at the front by the well-known McPherson Ford design of single transverse radius arms in connection with a torsion bar stabiliser and coil springs of considerable length. The rear suspension employs wide semi-elliptic springs having three leaves only.

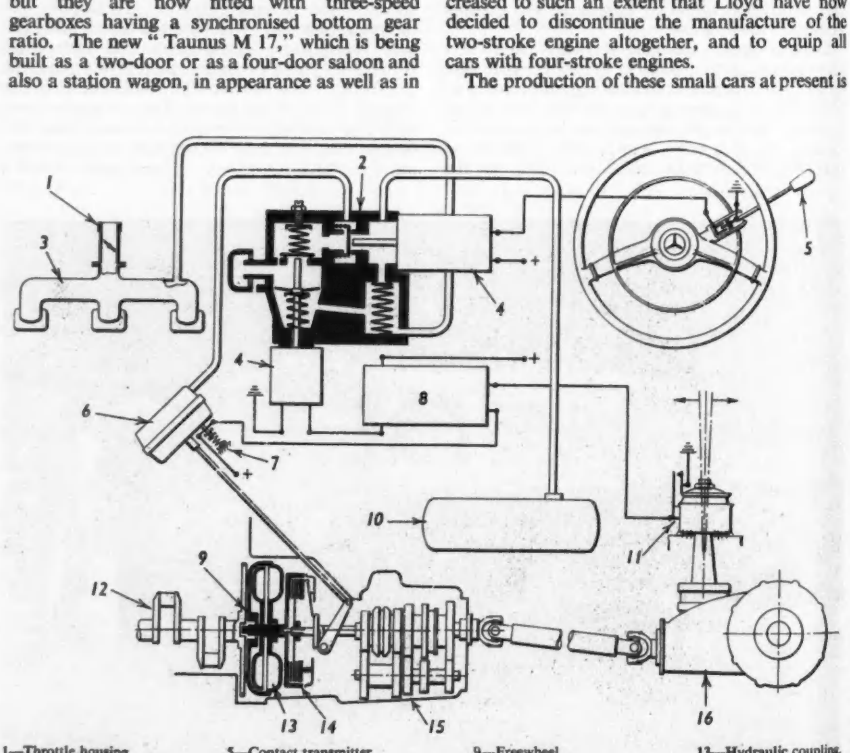
The 1·7-litre o.h.v. engine of 84mm bore and 76·6mm stroke resembles that of the British "Consul" ; it has a compression ratio of 7·1 : 1 and develops 60 h.p. at 4250 r.p.m., i.e. about 10 per cent more than that of the 1·5-litre engine of the "Taunus M 15," but with a corresponding torque increase of 18 per cent. Like the earlier engine it has a hollow crankshaft of spheroidal-graphite cast iron. The torque is transmitted from the engine via a fully synchronised three-speed gearbox and an open propeller shaft to the hypoid rear axle having a transmission ratio of 3·9 : 1. The latter can be increased to 4·44 : 1 on the optional addition of a Borg-Warner overdrive, an accessory now being made in Germany under licence by the Adler-Werke A.G. The car is also available with two-pedal control, in which case the "Saxomat" automatic clutch is being fitted ; this centrifugal clutch, with vacuum-operated withdrawal mechanism, will be described later on in our report.

The three amalgamated motor companies of Borgward, Goliath and Lloyd are showing a variety of cars, each individual firm presenting several versions of one basic model of entirely different character.

The Borgward "Isabella," a four-cylinder 1·5-litre car of modern design with independent all-wheel coil-spring suspension, is well known in this country ; apart from minor modifications in styling the car remains unchanged.

The Lloyd front-wheel drive car has a wheelbase of 7ft 6in and weighs only 9½ cwt ; this small four-seater of conventional but pleasing appearance has been supplied for some time either with a 400 c.c. two-stroke or with a 600 c.c. four-stroke engine. Since the introduction of the latter engine two years ago the demand for this more powerful unit has increased to such an extent that Lloyd have now decided to discontinue the manufacture of the two-stroke engine altogether, and to equip all cars with four-stroke engines.

The production of these small cars at present is



1—Throttle housing.
2—Control valve.
3—Inlet manifold.
4—Solenoids.
5—Contact transmitter.
6—Servo cylinder.
7—Limit switch.
8—Relay.
9—Freewheel.
10—Vacuum tank.
11—Rear-drive switch.
12—Crankshaft.
13—Hydraulic coupling.
14—Friction clutch.
15—Gearbox.
16—Final-drive casing.

The system for automatic clutch operation on the Mercedes "220"

The BMW "600" has a door in front of the driver and another on the near side

The S.A.A.B. "93" has a three-cylinder, two-stroke engine with liquid cooling

running at the rate of about 250 cars per day and it is claimed that the small Lloyd ranks, after the Volkswagen and the Opel "Olympia," in third place of all German new car registrations. The engine of the latest model Lloyd "Alexander" is particularly interesting: it is an air-cooled parallel twin-cylinder engine of 600 c.c. cylinder capacity which develops 19 h.p. at 4500 r.p.m. All engine bearings are either ball or roller bearings; the cylinder head is of aluminium with hemispherical combustion chambers, and the inclined valves are operated by rockers from a chain-driven overhead camshaft. The engine is transversely mounted in the tubular backbone chassis and drives the front wheels via a fully synchronised four-speed gearbox. The front suspension employs parallel transverse leaf springs with telescopic dampers; two of the five leaves of the top spring have reversed camber to provide a progressive spring characteristic and to serve as an anti-roll device.

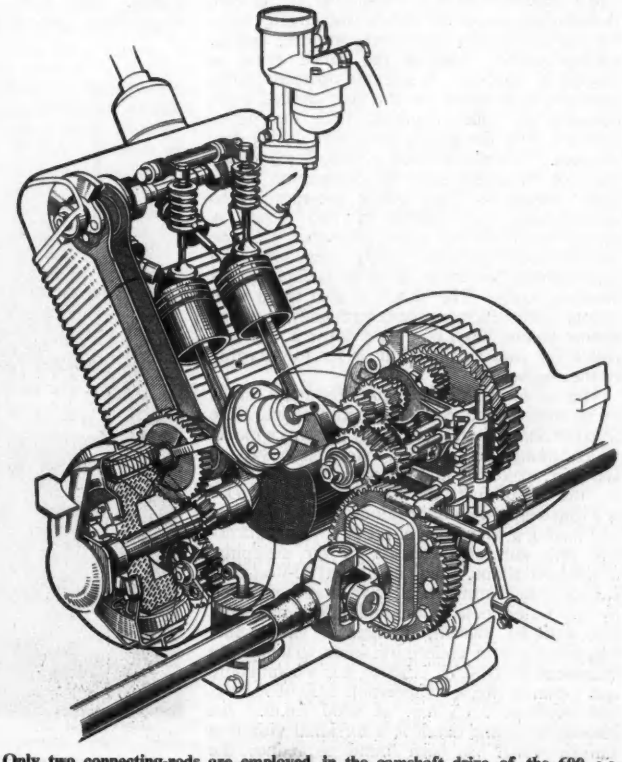
The replacing of existing two-stroke engines by modern high-efficiency four-stroke engines is also apparent at the stand of Goliath. Goliath front-wheel drive cars, for several years past, had been equipped with transversely mounted water-cooled, two-stroke, two-cylinder engines, originally of 700 c.c. and more recently of 900 c.c. cylinder capacity. The latter engine, when fitted with petrol injection, was designed to develop about 34 h.p. at 4000 r.p.m., an output which, to-day, is not considered sufficient for a four-seater car of 17 cwt kerbweight; further, the twin had a considerable rocking moment in the transverse plane, thus causing a certain amount of unpleasant vibration. The new Goliath "1100," illustrated on page 465, which makes its first public appearance at this year's show is of the same basic layout as the former Goliath "900," but it is fitted with a horizontally opposed 1·1-litre four-cylinder four-stroke engine. This engine, of 74mm bore and 64mm stroke, has a compression ratio of 7·3: 1 and develops 40 h.p. at 4250 r.p.m. It is of modern design with parallel push-rod operated overhead valves; the crankcase, the cylinder heads and the cylinder blocks are of light metal with wet centrifugally-cast iron liners. The engine and the fully synchronised four-speed gearbox are longitudinally mounted fore and aft of the front-wheel centres, and the drive is taken from the clutch through the final-drive casing to the first-motion shaft of the gearbox, and then back through the second-motion shaft to the bevel gear. The new engine is more powerful than the two-stroke engine it replaces and being, as a horizontally opposed four-cylinder, practically free from vibration, it should greatly improve the general performance and the handling properties of the Goliath car.

It has been known for some time that at least four of the big German motor-cycle manufacturers, concerned about the diminishing demand for their products, have been experimenting with small cars. After several years of extensive development some production models, based on motor-cycle design, have been evolved which are now making their first public appearance. A well-known example of previous design is the 300 c.c. "Isetta" of Bayerische Motorenwerke A.G., a compact egg-shaped vehicle for two adults and one small child. In spite of its entirely unorthodox shape the "Isetta," since its introduction some three years ago, has been a success at the home market as well as abroad, and more than 50,000 vehicles have so far been made. The Bayerische Motorenwerke are now presenting a new 600 c.c. rear-engine four-seater car, the design of which, like that of the "Isetta," is to a great extent based on components developed in motor-cycle practice. The B.M.W. "600" is a four-seater saloon of entirely functional though not unattractive appearance; it has a wheelbase of 9ft 10in and weighs 10¼ cwt. The steel body is bolted to a chassis built up from steel tubes, and carries at the rear the very compact engine-transmission unit. The body has some resemblance to that of the "Isetta," in so far as the front bench seat is reached through the forward facing counter-balanced door which swings open together with the universally jointed steering column. In addition to this front door the car has one conventional door on the near side giving access to the rear seats. The independent all-wheel suspension employs short longitudinal leading arms at the front and longitudinal trailing arms at the rear, in either case combined with coil springs and telescopic dampers.

The horizontally-opposed 585 c.c. two-cylinder overhead-valve four-stroke engine of 74mm bore and 68mm stroke is basically a de-rated version of the B.M.W. motor-cycle engine, but it has a centrifugal fan mounted on the crankshaft and cylinder cowlings. At a compression ratio of 6·5: 1 it develops 19·5 h.p. at 4000 r.p.m. compared to 28 h.p. of the standard motor-cycle engine and to 35 h.p. of the sports version. The thermostatically controlled air supply of the cooling fan can be utilised for car heating. The torque from the single dry-plate clutch is transmitted to the rear wheels via a fully synchronised four-speed gearbox and rubber-jointed half shafts.

Belonging in the same category of small cars powered by air-cooled two-cylinder engines as the Lloyd "600," the B.M.W. "600," and, incidentally, the Fiat "500" (which will be shown at the coming London Motor Show), the new "Prince" is made by N.S.U. Werke A.G., the biggest motor-cycle manufacturers in the world, of Neckarsulm. Unlike the B.M.W. "600," the "Prince," as far as appearance goes, is a typical conventional four-seater motor-car, suitably reduced in scale. It is built in all-steel integral construction, weighs slightly less than 10 cwt, and has a wheelbase of 6ft 7in, a track of 4ft, and an overall length of 10ft 4in. The suspension employs conventional double wishbones at the front, and swing axles at the rear, both fitted with coil springs enclosing the telescopic dampers. The steering is of the rack-and-pinion type with a divided track-rod, and the well-finned drums of the hydraulic brakes are of light alloy with cast-in iron liners.

The car is powered by a 600 c.c. twin-cylinder four-stroke engine which, integral with the four-speed constant-mesh gearbox and the final drive casing, is transversely mounted at the rear of the car. The engine below has hemispherical cylinder heads and inclined valves which, like those of the single-cylinder N.S.U. motor-cycle



Only two connecting-rods are employed in the camshaft drive of the 600 c.c. N.S.U. "Prince"

engine, are operated from an overhead camshaft driven by a system of eccentric link rods ; it develops, at a compression ratio of 7·2 : 1, 20 h.p. at 4800 r.p.m. The torque from the single dry plate clutch is transmitted through gears via the four-speed gearbox to the final drive casing, which is so arranged as to give equal lengths of driving shafts to the rear wheels. It is claimed that the maximum speed of the car is 65 m.p.h., and the fuel consumption at 30 m.p.h., about 70 m.p.g.

It would be wrong to assume from the predominant display of small cars fitted with four-stroke engines that in this particular field the two-stroke engine is likely to be discarded in the near future. In this respect designers are of different opinions, and the protagonists of the two-cylinder, two-stroke engine maintain that the unbalanced couple of the latter is less likely to cause unpleasant vibrations than the considerable inertia forces of the vertical twin four-stroke engine with a 360 deg. crank-throw angle. We observe that the production figures of the oldest and probably best-known two-stroke car, the 900 c.c. three-cylinder D.K.W. " Meisterklasse " of Auto Union A.G. is still running at the rate of more than 200 a day, and evidently this fast and reliable front-wheel drive car is still enjoying a well-deserved popularity. No changes have been introduced in this year's standard models, but a two-seater coupé and a roadster are now available, both fitted with a 50 h.p. 1-litre engine of the same basic design as the 900 c.c. standard engine. Further, a new, well styled four-seater saloon makes its first appearance ; like all the other DKW models it is fitted with front-wheel drive and a water-cooled, two-stroke engine. The engine, presumably a two-cylinder version of the 1-litre engine, is mounted longitudinally in front of the wheel centres and is fitted with a synchronised four-speed gear-box ; it is claimed to develop 30 h.p. at 4200 r.p.m. Apart from the fact that the car weighs about 12¼ cwt., and is designed for a maximum speed in excess of 65 m.p.h., no other technical details were available.

The two 1-litre models and, also, the four-door 900 c.c. saloon can be optionally fitted with the " Saxomat," a two-pedal control developed by Fichtel and Sachs A.G., which we have mentioned in our description of the Ford " Taunus M 17." This system, to some extent, resembles the " Newtondrive " which has been adopted for the smaller Standard cars, and comprises a centrifugal clutch of the single dry plate type and a vacuum-operated withdrawal mechanism. Bobweights engage the clutch centrifugally when the car is starting from rest, working against springs which disengage the clutch again as the car is stopped. A solenoid-operated valve, actuated by a switch on the gear change lever, connects the inlet manifold with the servo-cylinder, thus disengaging the clutch, during gear changes. In order to effect a smooth re-engagement of the clutch after the completion of the gear change, the atmospheric pressure in the servo-cylinder is restored in two steps. A spring-loaded control valve connected with the throttle keeps the latter partly open during all gear changes for the purpose of facilitating the changes down. The clutch is also fitted with simple pawls which engage centrifugally at engine speeds below 300 r.p.m. and form a one-way clutch for parking on a hill or for tow-starting of the engine.

The use of two-stroke engines for small cars is by no means confined to German practice. The Swedish Saab Aircraft Company presents a model which, though actually first marketed in Sweden last year, makes its first appearance in Germany at the Frankfurt show. The Saab " 93 " is a four-seater, two-door saloon weighing 16 cwt and having a wheelbase of 8ft 2in. This attractive little car, characterised by the sweeping, streamlined shape, is built in integral all-steel construction, has front wheel drive, and is powered by a water-cooled longitudinally mounted, three-cylinder, two-stroke engine. The engine, which in its entire conception seems to be greatly influenced by D.K.W. practice, has a 66mm bore and 73mm stroke, a compression ratio of 7·3 : 1, and develops 32·5 h.p. at 4200 r.p.m. An interesting engine detail is a torsional vibration damper which has been found to reduce the mechanically excited noise occurring quite frequently in the built-up crankshafts of two-stroke engines when mounted in ball or roller bearings.

The very compact three-speed gearbox with a lockable free-wheel between the clutch and the first-motion shaft of the box is mounted aft of the wheel centres ; it has two synchronised upper ratios and a dog clutch engagement for the bottom ratio. The front suspension is conventional, having double wishbones with coil springs, telescopic dampers, and a stabiliser bar. The rear suspension also employs coil springs and telescopic dampers ; the rear axle is a semi-stiff U-shaped structure joined to the body by a resilient bearing in the centre line of the car and, further, by two longitudinal trailing links. We had the opportunity of testing the Saab " 93 " and were surprised by its speed, flexibility, road-holding and, generally speaking, by its satisfactory handling properties it is depicted on page 467.

European Machine Tool Exhibition

No. II—(*Continued from page* 435, *September* 20)

A BRITISH manufacturer's stand which attracted a considerable amount of attention at Hanover was that of E.M.I. Electronics, Ltd., Hayes, Middlesex, on which there were shown two machines equipped with the firm's three-dimensional control system. For this system the data encoded on a punched paper tape is presented to a control unit, which deduces the movements to be made by the cutting tool and the workpiece to produce the required profile and passes the appropriate instructions to the servo controls of the machine. No separate computer is required as the control unit incorporates a parabolic interpolator which enables it to deduce, from a relatively small number of " marker " points in the table of dimensions, a large number of other points lying on a smooth curve through the " markers."

We illustrate in Fig. 9, a Cincinnati " Hydrotel " miller, exhibited for numerical control demonstration purposes by E.M.I. in which all the motions are controlled in three dimensions. In this machine the vertical movement of the cutter spindle and the longitudinal and lateral traverses of the worktable slide, are each equipped with servo controls and position identifying mechanisms, and the master control incorporates two interpolator units. These interpolator units can be applied to any of the machine motions to give continuous parabolic interpolation, while the motion in the third dimension is controlled at selected discrete points.

Normally, " three-dimensional " machining consists of many successive passes during each of which the machine cuts a two-dimensional contour, indexing in the third dimension between passes. This E.M.I. system fully meets this requirement, providing, as it does, constant monitoring in all three dimensions and continuous automatic control in any two chosen dimensions, with the remaining one capable of being set at selected discrete points. Thus, all normal three-dimensional machining (die sinking, &c.) is within its capabilities. The various slide motions on the " Hydrotel " machine are operated by hydraulic rams, with electro-hydraulic valves providing the link between the data control and the hydraulic system. The accuracy of the information given by the control system is stated to be within 0·0003in.

A new drilling machine specially built by Industrial Technics (Southampton), Ltd., incorporating the E.M.I. " Inductosyn " position control system, was also shown.

This new drilling machine will eventually be available in six variations on a basic design, with either co-ordinate positioning by punched tape only ; co-ordinate positioning by manual control only ; or co-ordinate positioning by both punched tape and manual control, and each of these three variations can be combined with automatic control of the drilling head. The accuracy claimed for the machine and control system is of a high order and positioning of the table is stated to be within ±0·0005in. With a standard drilling head of good quality fitted to the machine an overall accuracy of 0·002in to 0·003in is said to be obtainable, and with a jig boring head an accuracy of 0·001in to 0·002in is well within its capacity.

The equipment shown by Societe Genevoise included a new model of the " Hydroptic 6 " jig borer, which is known as the " 6A " and is available with an automatic co-ordinate repeating device, which is stated to have an accuracy of

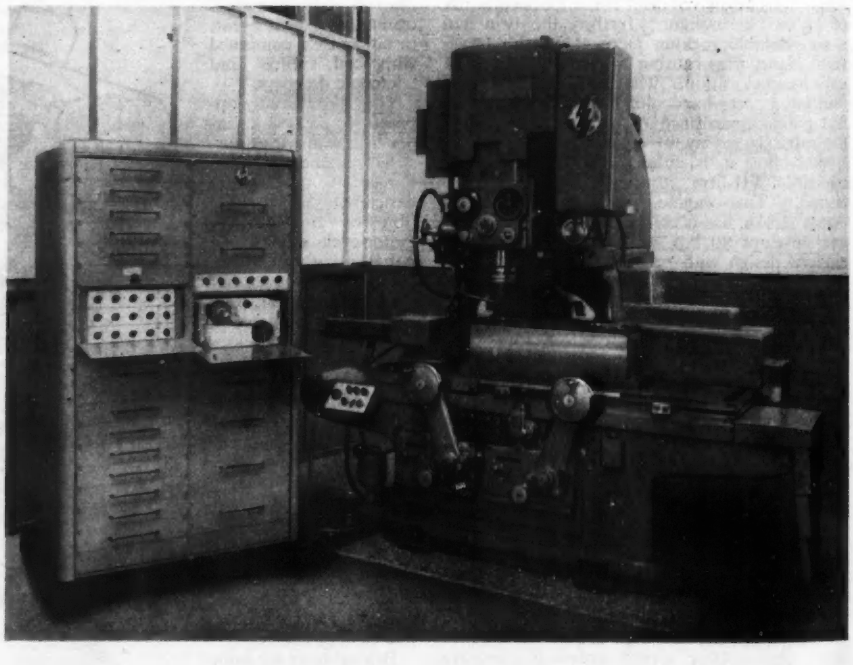


Fig. 9—Milling machine equipped with E.M.I. electronic three-dimensional control system—E.M.I.

repetition setting within 0·00004in. On this machine the 8 h.p. spindle motor is on the side of the head instead of at the top, as in the previous machine ; this lowers the centre of gravity so that the spindle head and saddle have a wider base to give increased steadiness on the cross rail. The spindle head is equipped with a device for the preselection of spindle speeds by means of a circular scale, and when the cutting speed has been chosen the corresponding spindle speed is obtained by setting the knob on the prescribed boring diameter. When the machine is in action, the operator can select the speed for the next operation and thereafter the speed is changed by pushing a single lever.

The repeating device, supplied as an optional extra with the machine, is intended to cut down unproductive time taken on co-ordinate settings. When machining the first of several workpieces, the operator registers each setting of the table and the spindle saddle by depressing a push button, acting instantaneously on either of the co-ordinates or on both simultaneously. This automatic repetition of the settings can be made in both directions along the co-ordinate axes. The operator can register twenty settings for each co-ordinate which can be cancelled singly or collectively. The operator can make additional hand settings at any time, and the origin of the co-ordinates may be modified without interfering with the registration of the centre distances.

At any time during production the operator can verify the precision of the automatic settings on the viewing screens.

The " Spacematic " automatic positioning jig boring machine made by the Newall Engineering Company, Ltd., of Peterborough, was described in our issue of June 29, 1956. The machine exhibited at Hanover incorporates a number of design modifications and is fitted with a two-dimensional tracer control which allows copy milling to extremely close tolerances. A machine with the preliminary experimental tracer equipment is shown in Fig. 10. The B.T.H. tracing head is used to control the independent d.c. drive to each slide of the machine, and preliminary trials have shown that, under satisfactory conditions, it is possible to maintain a copying accuracy within 0·0005in. With the existing attachment the cutting speed is steplessly variable from ¼in to 4in per minute. A further high-speed range will be added but it should be appreciated that higher cutting rates will naturally entail some loss in accuracy, particularly when abrupt changes in contour occur.

The direction of traverse may be selected so that either conventional or " climb " milling may be performed, special back-lash eliminators being incorporated in the table drives. Change-over from normal automatic positioning to tracer control is effected by one switch only, so that components having profile surfaces in addition to precise bores or rectilinear surfaces can be machined at one setting.

In the production machine the control station will be incorporated in the console on the front of the machine, the tracer head will have a rigid mounting, and an auxiliary model table having a 2in adjustment along two right-angular co-ordinates will be mounted overlapping the ways guards at the left-hand end of the table. To ensure maximum rigidity of the tracer head, which has a direct bearing on copying accuracy, it is proposed to limit the copying area to 26in by 26in, but, by special arrangement, it will be possible to increase one of these co-ordinates.

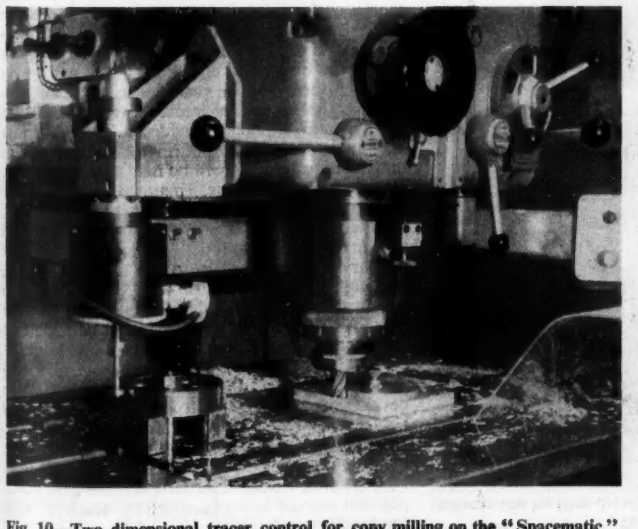


Fig. 10—Two dimensional tracer control for copy milling on the " Spacematic " automatic positioning jig boring machine—Newall

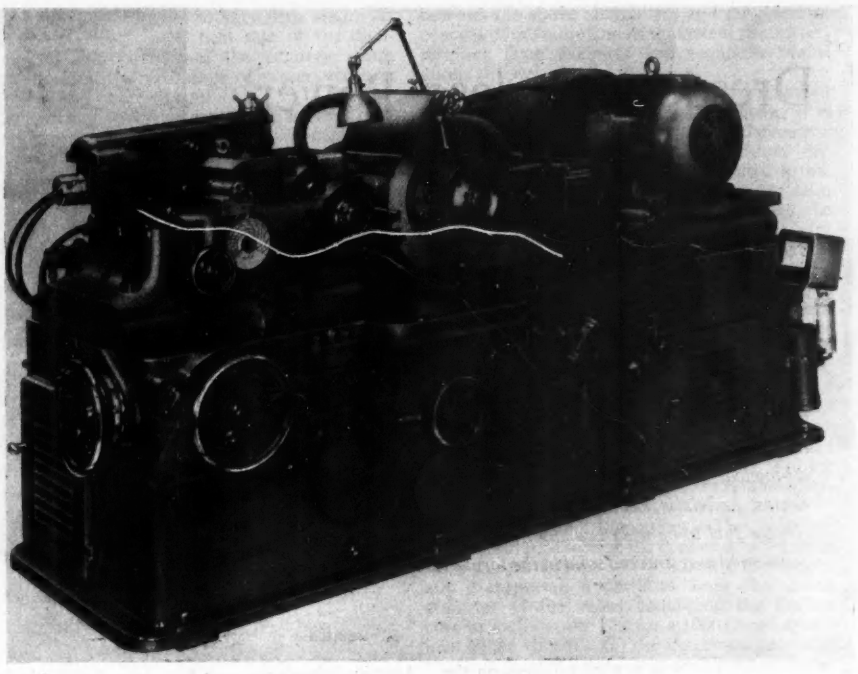


Fig. 11—24in wheel centreless grinder—Lidkoping

A new centreless grinder made by Lidkopings Mekaniska Verkstads A.B., of Sweden (Fenter Machine Tools, Ltd., Birmingham), with a standard wheel width of 24in, is particularly suitable for handling work such as long spindles and for the through grinding of relatively short workpieces from 0·4in to 8in diameter. During the exhibition it was shown operating with fully automatic grinding of rocker arm shafts using a pneumatically operated infeed attachment. In this machine (Fig. 11) the spindles of the 20in grinding and the 13in diameter regulating wheels are mounted in two double-row roller bearings and the grinding wheel spindle is driven through a torsion bar to relieve it of belt tension. The grinding wheel has a maximum speed of 1510 r.p.m. and the regulating wheel has a steplessly variable speed range up to 115 r.p.m. Through feed can be effected in both directions as the regulating wheel is tiltable towards both sides. A push-button controlled resetting device for compensation of grinding wheel wear is stated to give an accuracy of 0·00008in and hydraulic profile truing devices are fitted for both wheels.

A smaller machine on the stand was fitted with the firm's pneumatic-electric size control attachment, which can also be fitted on the new large machine. This attachment continuously checks the finished workpieces and automatically resets the machine to compensate for tolerance deviations. When an undersize piece passes into the attachment a red indicator lights, the loading gear stops, and subsequent workpieces in progress are diverted to a separate box. When the upper tolerance limit is approached an impulse is transmitted by the gauging equipment to the grinding wheel resetting mechanism, which advances the wheel by 0·0003in to 0·00004in, according to the preset required accuracy of finished parts. In the event of oversize parts being produced, a red indicator is lit, the loading gear stops and subsequent parts are diverted to an oversize box.

(To be continued)

Sunlight Analyser for Architectural Models

When a building or group of buildings is being planned, it is usually desirable to determine the amount of sunlight received at various times of the day and year, and whether some of the structures take away any light from others, possibly to an undesirable extent. An improved " heliodon," or apparatus for investigating such problems by means of model tests has been constructed at Delft Technical University. The instrument comprises a circular table on which the model is set up and which can be rotated and tilted in a frame rather like that of a dressing-table mirror. The frame is rotatably mounted in the centre of a U-shaped beam, the ends of which are cradled in the base in such a manner as to enable the beam to tilt about a horizontal axis. The principal frame parts are tubular.

All axes of rotation pass through one point, viz. the centre of the model table. The axis of rotation of the table is at right angles to its axis of tilt, which in turn is at right angles to the axis of rotation of the frame, which again is at 90 deg. to the pivots of the supporting beam.

Illumination representing the sun is obtained from a searchlight set up with its centre line horizontal and at right angles to the axis of the U-shaped beam. The apparatus is set by tilting the model table to the correct angle of latitude as measured on a graduated scale, and setting the U-shaped beam, which can be tilted forwards or backwards by 23° 27′, to correspond to the height of the sun on the particular day of the year for which the investigation is being made. Lastly, the table frame is rotated to correspond with solar time, which must be calculated from the local time assumed for the test.

The model itself can be quite a simple affair made of blocks of wood stuck to a photographic map of the proposed site. By rotating the model table, the effect of varying the orientation can rapidly be studied for any state of the sun.

Dresden Nuclear Power Station in Illinois

BY OUR AMERICAN EDITOR

No. I

On June 12 last major construction commenced on the Dresden nuclear power station of the Commonwealth Edison Company near Chicago, Illinois. A view of the site works is reproduced here. A 190ft sphere will house a General Electric dual-cycle boiling water reactor and a turbo-generator. At present the 180MW plant is the largest all-nuclear power station under construction in the United States, and it is expected to be completed by 1960. The reactor fuel to be used is a slightly enriched uranium dioxide fabricated as a sintered solid in the form of a cylindrical pellet.

CONSTRUCTION is now in progress on the Dresden nuclear power station of the Commonwealth Edison Company in Illinois. The scheme comprises a 180MW electric generating plant and is the largest privately financed current American atomic power project. The nuclear reactor and turbo-generator plant is being designed and built by the General Electric Company, of Schenectady, New York. It will be situated 50 miles southwest of Chicago at the confluence of the Des Plaines and Kankakee rivers. The station is being built for the Commonwealth Edison Company and the members of the so-called American Nuclear Power Group for 45,000,000 dollars. This group is composed of the American Gas and Electric Company, the Bechtel Corporation, the Central Illinois Light Company, the Commonwealth Edison Company, the Illinois Power Company, the Kansas City Power and Light Company, the Pacific Gas and Electric Company and the Union Electric Company of Missouri. The station is to be in service by 1960. Design started in April, 1956, and site construction in June last.

The Atomic Power Equipment Department of the General Electric Company is conducting a research programme to develop the reactor design details and to advance boiling water reactor technology. The equipment to be utilised for this work includes a developmental boiling water reactor, having a steaming capacity sufficient for a 10MW plant. Half the steam will power a 5MW electrical output plant and the remainder will be dissipated in heat exchangers. This plant, together with a critical experiment plant and a "hot" laboratory, are all now under construction at the General Electric Vallecitos Atomic Laboratory near San Jose, California.* Additional equipments for heat transfer, corrosion, flow testing, and mechanical testing, are being constructed and placed in operation at San Jose. Fig. 1 shows the pressure vessel for the boiling water reactor being made ready for installation in a 100ft high containment vessel at the Vallecitos laboratory.

Because the conditions under which the project design is being carried out are somewhat different from those of government-sponsored nuclear projects, a brief review of the principal objectives is of interest. (1) The total power cost, based on the book value and the operating cost, is to be approximately equal to a conventional power station in this area. (2) Minimising of capital costs is a major concern. A primary aim of this undertaking is to contribute to the economic progress of a nuclear power industry. (3) The design must make adequate provision for public health and safety requirements.

The Dresden nuclear power station is situated on a site approximately 1½ miles long and 1 mile wide, adjacent to the junction of the Des Plaines and Kankakee rivers. The immediate vicinity is not heavily populated, although several communities ranging from 350 to 7000 population are situated within a 10 mile radius. A steel sphere, 190ft in diameter, encloses the reactor and associated auxiliaries to contain contamination in the unlikely event of a major nuclear incident. The turbine building, the irradiated fuel storage building, the administration building, the control room and similar facilities, are situated outside the sphere.

* An operating licence for the 5MW nuclear generating plant was issued to the General Electric Company by the U.S. Atomic Energy Commission on August 31. This constitutes the first American operating licence granted to a private industrial atomic power plant.

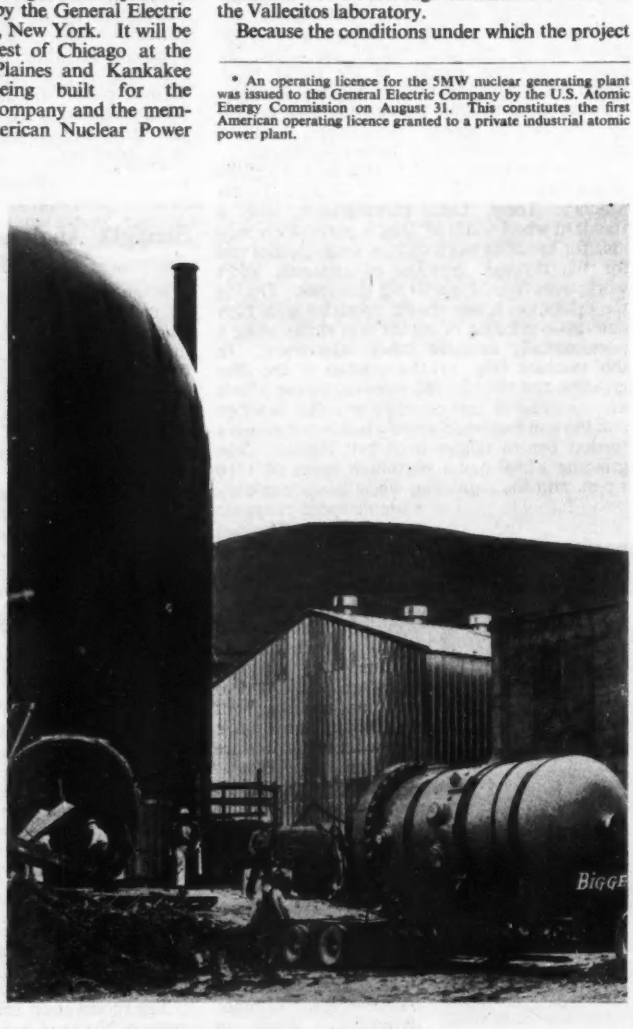


Fig.1—Pressure vessel for experimental boiling water reactor entering containment vessel at the Vallecitos laboratory

Fundamental Design

The conditions which will satisfy the project objectives are: 180MW net electrical output at 0·85 power factor and 75 deg. Fah. temperature of the condenser cooling water; capability for operation at 60 per cent capacity factor; total energy costs approximately comparable to those of the most efficient stations in the Commonwealth Edison system. Some of the more important design criteria are as follows: (1) An enclosure is to be provided capable of preventing the spread of radioactive materials in the event of a nuclear incident. (2) Personnel may enter the enclosure during normal operation but the requirements will be held to a minimum. (3) Wherever feasible, maintenance will be performed by direct contact rather than through remotely controlled operations. (4) A centralised system of plant control will be provided. (5) The primary nuclear fuel is to be uranium oxide, although modifications of core design and the substitution of new fuels after start-up will be provided for. (6) Components will be adequate for an anticipated operating life comparable to conventional power station equipment. (7) Aspects of design most likely to represent future development trends are to be emphasised. (8) The critical reactor parameters are as follows: (*a*) 300,000 B.Th.U. per hour per square foot maximum fuel element heat flux; (*b*) 3000 deg. Fah. uranium oxide fuel temperature; (*c*) 2·5 per cent reactivity compensated by steam voids in the reactor moderator.

Dual-Cycle Boiling Water Reactor

The dual-cycle boiling water reactor was selected as the best solution to fulfil the above design requirements, although other methods were considered. The dual-cycle boiling water reactor, as developed by General Electric, is a modified form of the direct boiling cycle which was pioneered by the Argonne National Laboratory. In the direct cycle, steam is generated in the reactor container and sent directly to the turbine. The cycle is very simple, since it has a single loop, no heat exchangers, and the turbine and reactor pressures are essentially the same. Its principal advantages are a good thermal efficiency for a given coolant temperature in the reactor, and its simplicity, which facilitates low capital cost per kW. For use in large central stations, it was desirable to modify the direct cycle to improve the power output per unit of core volume and the reactor response to load demand. Both of these objectives are related to the variation of nuclear reactivity with density changes caused by boiling.

The dual-cycle approach is to remove as much energy as possible by boiling in the upper part of the reactor without exceeding the limit of reactivity for good stability. A simplified flow diagram of this cycle is shown in Fig. 3. The boiling portion is controlled by the degree of sub-cooling at the inlet to the reactor. To accomplish this, the steam-water mixture is sent to a separating drum and the steam, which is essentially at reactor pressure, then flows directly to the turbine. The saturated water flows from the drum through heat exchangers where some energy is removed to produce steam at a somewhat lower pressure. This secondary steam is admitted to a lower stage of the turbine. The fraction of energy removed by means of the heat exchangers controls the temperature of the water returned to the reactor.

Load response is expected to be good. The pressure in the reactor is held constant by the turbine regulating valve, which controls the primary steam rate. Load changes are met by the actuation of the secondary admission valves by the turbine governor. Decreasing the rate of secondary steam production results in higher temperature water returning to the reactor. This decrease in sub-cooling causes the pressure in the secondary system to vary with load. As would be expected, the heat rate of the dual-cycle is contingent upon the primary steam pressure and the percentage of power which is removed as primary steam.

The design of the Dresden station is based on a combination of long-established practice and conditions sufficiently advanced to make a substantial contribution to the art. Many of the decisions made in establishing the design are based on a desire to keep the design as simple as possible with a minimum of equipment and to take advantage of the inherent stability, simplicity and safety of the dual-cycle boiling reactor. In designing the system consideration was given to various alternate schemes of which some of the more important ones were : a range of system pressures, sub-cooling by heat exchanger or flash tank, superheating with fossil fuel, use of a heat exchanger between the primary steam and the turbine, forced versus natural circulation, internal versus external steam separation, and various recirculation pumps and pumping systems. A brief discussion of the choices made between the above alternatives and the selection of some of the more important system parameters resulting from technical and economic evaluations follows.

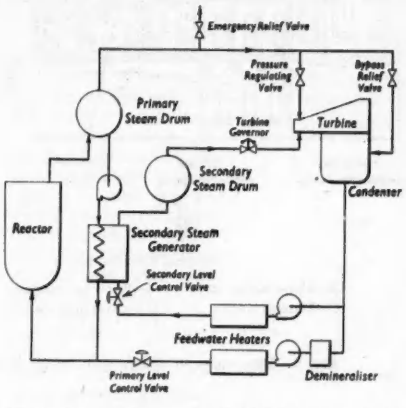


Fig. 3—Flow diagram of 180MW General Electric nuclear power station

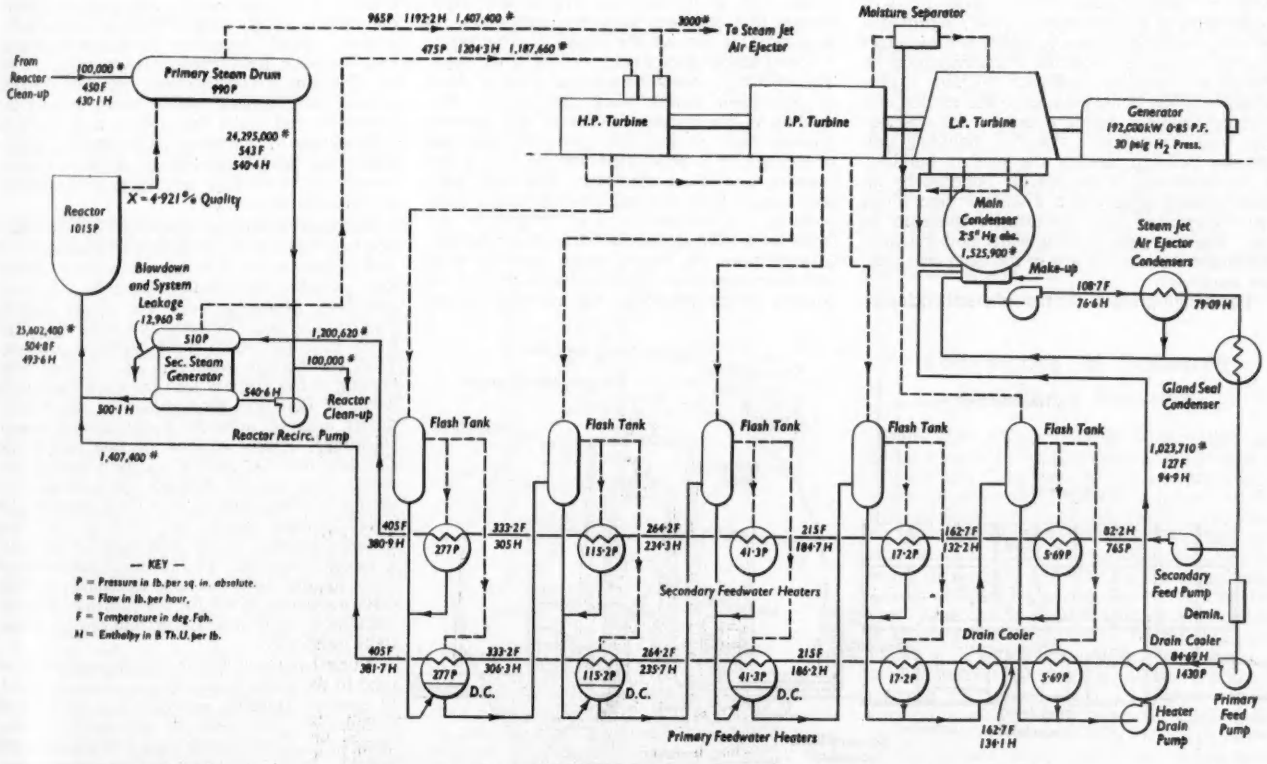
Primary to Secondary Steam Ratio.—To avoid instability, or "chugging" in the reactor, it is necessary to limit the steam formed in the reactor core. Economic studies to determine how this condition could best be satisfied resulted in the selection of a primary to secondary steam ratio of 1·2. These studies required balancing the effect of various coolant flow rates, auxiliary power demands, heat exchanger requirements and thermal efficiency.

System Pressure.—Primary pressures of 600 lb and 1000 lb per square inch gauge were considered. The higher value was selected as the fuel savings from a 10 per cent improvement in the heat rate outweighed the higher capital cost. The surface temperature limitations of the fuel elements made a consideration of higher pressures unfavourable. The net station heat rate for the 1000 lb per square inch gauge system is calculated to be 11,893 B.Th.U. per kilowatt-hour. For the 600 lb per square inch gauge system, the corresponding figure is 13,150.

Core and Fuel Dimensions.—The principal considerations affecting the core and fuel dimensions are as follows :—(*a*) Existing fabrication and transportation facilities limit the inside diameter of the vessel containing the nuclear core to slightly over 12ft for a 1000 lb per square inch gauge system ; (*b*) the maximum allowable heat flux is set at approximately 300,000 B.Th.U. per hour per square foot, and the calculated fuel element temperature should not exceed 3000 deg. Fah.; (*c*) various mechanical problems made a core length greater than 10ft undesirable. Balancing these various factors to obtain optimum conditions results in the selection of a core approximately 10ft in diameter with an active length of 9ft and consisting of about 700 fuel channels.

Steam Separation.—An external drum was selected to ensure an adequate separation of steam and water. Moisture carry-over to the turbine and possible cavitation in the recirculating circuit are considered important.

Forced versus Natural Circulation.—Forced circulation is used because it provides for positive



Gross generator output, kilowatts	192,000	Steam rate to turbine, #/kilowatt-hour, gross	13·52	Reactor and system losses, megawatts	627·3
Auxiliary power, kilowatts	12,000	Reactor heat output, no losses, megawatts	624·2	Net station heat rate, B.Th.U. per kilowatt-hour	11,893
Net station output, kilowatts	180,000	Reactor heat output, per cent	1/2	Plant thermal efficiency, per cent	28·7

Fig. 2—Heat balance diagram of Dresden nuclear power station

control and distribution of the core flow.

Enclosure.—Various kinds of enclosure, including underground vaults, dome-top cylinders and spheres for both complete and partial plant containment were considered. A sphere containing only the reactor and selected auxiliaries was found to provide the required safety most economically and with a better physical arrangement.

Recirculating Pumps.—The desire for eliminating shaft sealing problems led to the selection of the canned rotor pump for reactor recirculating duty.

Heat Exchanger versus Flash Tanks.—The heat exchanger rather than the flash tank was selected as the means of sub-cooling because of the lower auxiliary power required for pumping the reactor recirculating water, and because of the simplicity of primary flow control.

Heat Exchanger for Primary Steam.—The use of a heat exchanger in the primary steam, as well as in the secondary steam, was considered. This was discarded because it was more expensive, resulted in lower thermal efficiency, and because it was felt that radioactive steam could be handled successfully in the turbine cycle.

Design of Power Plant

The heat balance diagram at rated load is shown in Fig. 2, and indicates the main flow paths as well as cycle performance. The steam flow requirements to meet the 180MW net electrical output at 2½in Hg back pressure are 1,407,000 lb per hour at 1000 lb per square inch gauge and 1,188,000 lb per hour at 500 lb per square inch gauge. The calculated net station heat rate is 11,893 B.Th.U. per kilowatt-hour and the corresponding reactor heat output is 627MW.

Figs. 4 and 5 show the general arrangement of the reactor building, turbo-generator building and the fuel handling building. The reactor and its auxiliaries are installed in a sphere with the turbo-generator and its auxiliaries in a turbine building external to this sphere. The major items of equipment in the reactor building are the reactor vessel, the primary steam drum, secondary steam generators, the recirculating pumps and the main biological shielding. The turbo-generator set, the control room, the demineraliser equipment and the usual turbine room auxiliaries are in the turbine building. Sufficient compartmentation for major items of equipment, or groups of equipment, is provided so that maintenance can be performed by direct contact during the operation of the remainder of the plant. Sufficient biological shielding is provided to allow limited access to the reactor and turbine buildings during operation for observation and inspection. The fuel handling and storage building adjoins the reactor building. It is connected to the reactor building by an underground canal and a discharge tube which may be isolated from the exterior when not in use. An emergency cooling water tank provides cooling in the event of loss of the main heat sink, the condenser.

The design pressure for the spherical enclosure is 29·5 lb per square inch gauge. The design of the sphere conforms to the section VIII of the A.S.M.E. Boiler and Pressure Vessel Code with certain exceptions. These exceptions include the absence of pressure relief valves and of stress relieving of the final welds. To conform with the stresses allowed by the Code at the design pressure the plate thickness is 1¼in at the top and about 1⅝in at grade level. The lowest point of the sphere is 39ft below grade. A thorough testing procedure to ensure the sphere integrity and the absence of leaks is being planned.

Normal access for personnel and equipment into the sphere is provided by three pressure locks. Each of these locks has two doors in series, with an interlocking arrangement which ensures that one door is closed at all times. A large opening through the sphere is provided by a bolted access door, which is 17ft in diameter. This opening permits the removal of large pieces of equipment during plant shut-down. Seal welding is employed to maintain this opening pressure tight during operation. The bottom of the sphere is penetrated vertically by a fuel transfer tube 6ft in diameter. This tube leads into a canal from the fuel handling and storage building. Additional openings, ranging in size from 2in to 60in in diameter provide for the flow of ventilation air, steam, water, electric wiring and instrumentation. Steel columns around the equator of the sphere provide its only support during erection. After the completion of the enclosure a bowl-shaped concrete foundation will be poured under the sphere for the purpose of carrying the load of equipment and shielding inside the sphere.

The turbine building houses the turbo-generator, main condenser, feed pumps, feed water heaters, related main power loop equipment and most of the auxiliary station equipment. The building is 212ft wide and 92ft high. The turbine bay is 147ft long, 90ft wide and 92ft high, and most of it is occupied by equipment requiring biological shielding. The non-radioactive area of the building houses the station control room and other items such as switchgear, exciters, instrument and service area equipment, one of two battery rooms, heating boilers and a standby diesel generator unit. In general, ventilating air flows from areas where there is no possibility of radioactive contamination through various cells, general piping areas, around the condenser and under the turbine, and finally to exhaust fans discharging to the stack. Access areas are maintained at a slightly positive pressure to prevent the possibility of a backflow of contaminated air.

Biological shielding is provided against radiation consisting of neutrons from the reactor core and gamma rays. The source of these gamma rays includes contributions from N_{16} and O_{19}, corrosion products from the entire system, fragments of fuel elements, and induced activity from materials which have captured neutrons. With the possible exception of the feed-water flowing to the primary feed pumps, there will be levels of radiation throughout the entire main power loop of sufficient magnitude to require shielding. Except at one or two points, the shielding material used is standard density concrete. The use of shielded compartments for groups of equipment is used with provision for isolating these groups by valving. Servicing during operation of the remainder of the plant is thereby possible. In addition, provisions are made for the use of portable shielding in certain cases and space is left for the future addition of shielding in some areas if it is found by experience to be necessary.

A brief summary of the constructional materials used in the main power loop is given in Fig. 6. In general, stainless materials are used on all surfaces in contact with the primary fluid during operation. Carbon steel is used in the secondary system. In the unloading cooling system, which is used only when the plant is out of service, stainless materials are employed on the reactor

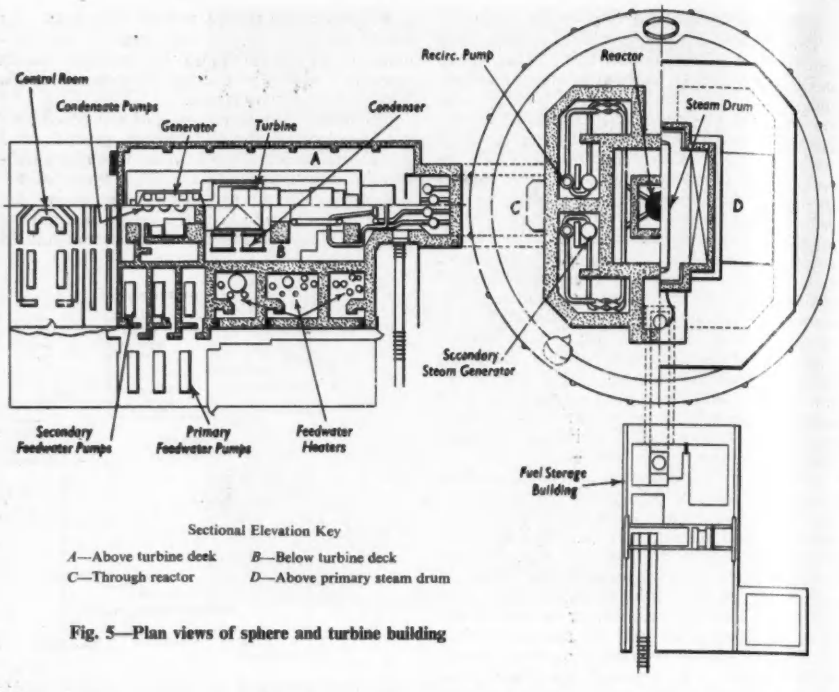


Fig. 5—Plan views of sphere and turbine building

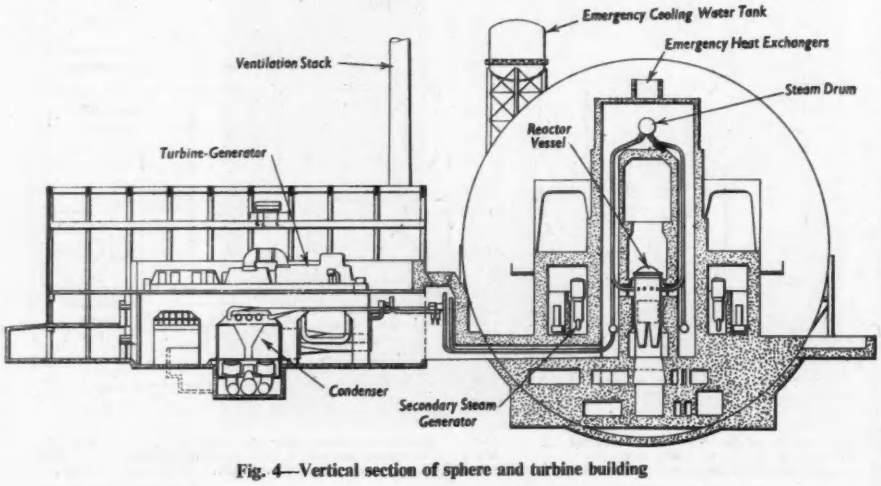
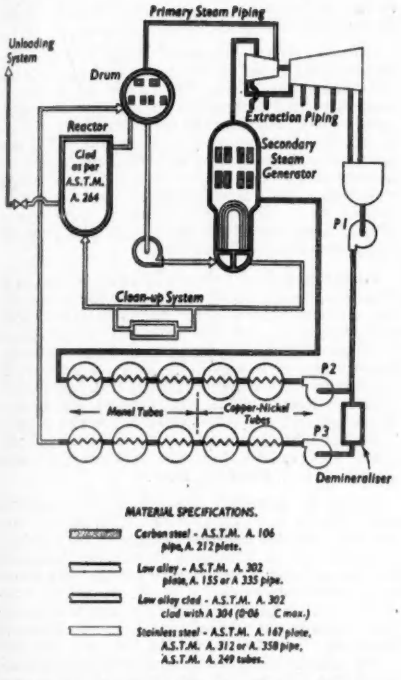


Fig. 4—Vertical section of sphere and turbine building

side of the shut-off valves and carbon steel in the remainder of the system. Carbon steel is used throughout the main steam and condensate system with a few exceptions. Generally, the turbine metals are conventional materials for the rated steam temperature and pressure. Alloys of higher chromium content, however, are used in areas which appear most susceptible to erosion and corrosion. The condenser materials are essentially conventional. "Monel" tubes are used in the three top feed-water heaters to provide adequate corrosion resistance. The stainless steel of the primary system begins at the shut-off valve following the last feed-water heater in the primary stream.

Reactor Plant

In describing the reactor system reference is made again to the heat balance diagram shown in Fig. 2. Energy produced in the reactor core is absorbed by water flowing through the fuel channels. The resulting steam-water mixture then flows to an external separating drum.


Primary Steam Piping
Unloading System
Drum
Reactor
Clad as per A.S.T.M. A. 264
Extraction Piping
Secondary Steam Generator
P1
Clean-up System
P2
Monel Tubes
Copper-Nickel Tubes
P3
Demineraliser
MATERIAL SPECIFICATIONS.
Carbon steel - A.S.T.M. A. 106 pipe, A. 212 plate.
Low alloy - A.S.T.M. A. 302 plate, A. 155 or A 335 pipe.
Low alloy clad - A.S.T.M. A. 302 clad with A 304 (0·06 C max.)
Stainless steel - A.S.T.M. A. 167 plate, A.S.T.M. A. 312 or A. 358 pipe, A.S.T.M. A. 249 tubes.

Turbine : conventional materials with certain exceptions.
Condenser : tubes, phosphorised Admiralty ; tube sheets, Muntz metal ; shells, carbon steel ; hot well trays and baffles, stainless steel.

Fig. 6—Diagram of construction materials used in the main power loop of the power plant

Sufficient drum internals are supplied to give the desired purity of the steam flowing to the turbine. Good separation is also required to eliminate the possibility of cavitation in the recirculating pumps. The water from the separating drum is pumped through the secondary steam generators which extract heat from the fluid, produce secondary steam and cool the water to give the desired sub-cooling before returning it to the reactor vessel.

There are four separate recirculation loops, each consisting of a secondary steam generator, recirculating pump and secondary valving. Each loop can be isolated as a unit. The steam-water mixture produced in the reactor vessel flows through the riser pipes to the primary drum, which is centrally located approximately 85ft above the reactor vessel. The downcomers feed two lower headers, which in turn supply the pumps and secondary steam generators. The primary steam drum is sufficiently high to permit the fuel handling operations to take place in the space between the drum and the top of the reactor vessel. Each heat exchanger and pump unit is installed in a separate shielded compartment. After a unit is isolated from the remainder of the system, maintenance in the individual cells can be performed on an eight-hour basis. The plant is capable of stable operation with one or two of the secondary loops out of service.

The primary steam drum is designed to provide about 1700 cubic feet of water storage volume. It is about 8ft 6in in diameter and 60ft long. The drum serves the dual part of reservoir and separating device. The drum size is determined by surges between the reactor vessel and the drum during transient conditions rather than on a steam-water separation basis alone. Steam-water separation is effected by using conventional equipment. The high drum arrangement produces good natural circulation characteristics and increases the available natural pump suction head.

The reactor recirculating pumps are completely sealed. The bearings are made of "Graphitar" and consist of two guide bearings and a Kingsbury thrust bearing. Water is circulated through the motor by an internal water circulating pump, to provide bearing lubrication and cooling. A heat exchanger is provided external to the motor stator to transfer heat through the motor casing to the low-pressure cooling water. The pump is designed so that the motor and pump internal components can be easily and quickly removed from the pump bowl for maintenance, leaving the pump bowl in the piping system. Both the rotor and stator are canned to prevent water from penetrating the windings. A thermal barrier is designed in the pump and motor combination to minimise heat transferred from the pumped fluid to the motor section.

In Fig. 7 we show a section of the vertical secondary steam generators which produce steam at 500 lb per square inch gauge. The primary fluid is pumped through the inverted U-tubes. The secondary fluid and the steam separation

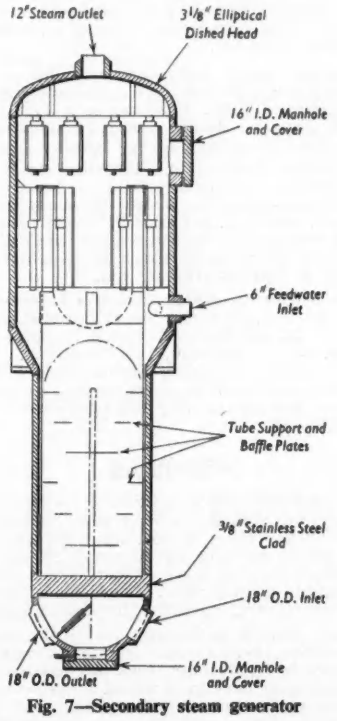

12" Steam Outlet
3 1/8" Elliptical Dished Head
16" I.D. Manhole and Cover
6" Feedwater Inlet
Tube Support and Baffle Plates
3/8" Stainless Steel Clad
18" O.D. Inlet
16" I.D. Manhole and Cover
18" O.D. Outlet

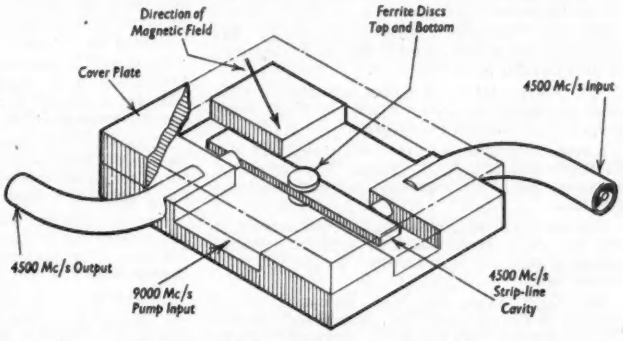
Fig. 7—Secondary steam generator

equipment are contained in the vertical cylindrical shell. An emergency cooling heat exchanger is required to remove the reactor decay heat in the event of loss of the main condenser. Steam from the reactor is condensed by water stored in an emergency storage tank, and this water is evaporated to atmosphere. Sufficient storage is provided in the cooling water tank to take care of the decay heat for several hours after shutdown. To remove the reactor decay heat during an unloading operation, a separate circuit is provided. In this system primary water is pumped through a heat exchanger, transferring heat to the river water.

(To be continued)

Solid-State Microwave Amplifier

A NEW solid-state microwave amplifier using a ferrite material as the active element, has been successfully operated at the Bell Telephone Laboratories, of New York. One experiment conducted at the Bell Laboratories is indicated in the accompanying diagram. To simplify the circuitry, each of the two signal frequencies was made approximately 4500 Mc/s. The pumping



Experimental ferrite microwave amplifier

power of 9000 Mc/s was fed into the resonant cavity, as shown, and the signal power taken in and out by means of co-axial cable. With sufficient pumping power, oscillations took place at 4500 Mc/s. When the pumping power was reduced somewhat, amplification was observed at 4500 Mc/s. In the experimental arrangement, the d.c. magnetic field of about 2500 gauss was provided by an electromagnet, but a permanent magnet could be employed if desired. The field was parallel to the plane of the strip-line cavity and oriented at an angle of about 45 deg. with the cavity. In another experiment, a cavity was designed to be resonant at the two frequencies of 4000 Mc/s and 4800 Mc/s, with the pumping frequency set at 8800 Mc/s. Oscillations and frequency conversion were observed at both the lower frequencies. The action of the ferromagnetic amplifier can be simulated at low frequencies by a pair of ordinary resonant circuits coupled by a variable inductance or capacitance. Since certain very-high-frequency atomic phenomena also have this circuit analogue, it is possible that the same amplification principle will find applications at frequencies much higher than those now in use.

Construction of Seventeen Low-Power Reactors

THE U.S. Atomic Energy Commission has issued permits to Aerojet-General Nucleonics of San Ramon, California, for the construction of seventeen low-power research reactors and for the modification of an existing reactor to increase its power level. Sixteen of the seventeen new reactors to be built are to be 100 milliwatt equipments (designated AGN-201) of the same design as four reactors licensed earlier by the Commission. One new reactor (designated AGN-201M) is to be a 5W modification of the AGN-201 reactor. In addition, the company proposes to modify one of its licensed 100 milliwatt reactors to increase the power level to 5W. Aerojet-General Nucleonics has advised the Commission that the reactors are to be built for sale to various universities and other institutions. It has asked for authority to transfer the reactors, without further application by the company, to purchasers licensed by the Commission to possess and operate the facilities.

Personal and Business

Appointments

MR. ALAN GRAHAM has been appointed assistant general manager (castings) of High Duty Alloys, Ltd.

MR. PHILIP GOMEZ has been appointed marketing training manager of Texas Instruments, Inc., Dallas, Texas.

DR. M. U. WILKES, F.R.S., has accepted the invitation of the British Computer Society to become its first president.

MR. GEORGE HILTON has been appointed managing director of Scotts' Shipbuilding and Engineering Company, Ltd.

SHEEPBRIDGE STOKES, Ltd., has announced that Mr. J. J. Carroll has joined the company as manager of the single cast ring foundry.

HAROLD ANDREWS SHEEPBRIDGE, Ltd., has announced the appointment of Mr. A. E. Akerman as sales director of the company.

MR. NORMAN HARVEY has been appointed development manager of the Aston Chain and Hook Company, Ltd., Erdington, Birmingham.

KAYSER, ELLISON AND CO., Ltd., states that Mr. H. Baron and Mr. A. B. Heeley, directors of the company, have been appointed assistant managing directors.

THE UNITED STEEL COMPANIES, Ltd., has announced that Mr. A. J. Peech has been appointed general managing director in succession to the late Mr. Gerald Steel.

MR. DAVE PAYNE has been appointed service manager of Rotary Hoes, Ltd., in succession to Mr. D. Middlemiss, who has been appointed deputy commercial manager.

MR. W. C. CLEGG has been appointed purchasing agent, Metropolitan-Vickers Electrical Company, Ltd., in succession to Mr. G. T. King, who has retired from executive duties.

MR. D. F. GRANT, A.M.I.E.E., has been appointed chief generation engineer (operation), North West, Merseyside and North Wales Division of the Central Electricity Authority.

PLENTY AND SON, Ltd., announces that Mr. J. D. Mellor has retired after more than forty years' service with the company. Mr. S. R. F. Drake has been appointed a director.

SILVERTOWN RUBBER COMPANY, Ltd., states that Mr. J. Westhead has been appointed works superintendent at the Silvertown factory. Mr. W. Lessing has been appointed technical manager.

LONDON TRANSPORT has announced the appointment of Mr. G. Yorke as divisional superintendent "C," in charge of the District and Piccadilly lines. He has also been made an officer of the Executive.

MR. L. J. W. BAILEY has been appointed a director and general manager of the India Tyre and Rubber Company. He has been succeeded as chief purchasing agent of the Dunlop Rubber Company, Ltd., by Mr. D. W. Hawkins.

MR. R. P. CRAWSHAW has been appointed general sales manager of the United Steel Companies, Ltd. He succeeds Mr. H. M. Henderson, who is to take charge of the company's interests in Patchett Steel Construction (Pty.), Ltd., Cape Town.

DR. J. F. SHANNON, M.I.Mech.E., has been appointed chief engineer of the gear engineering department of Metropolitan-Vickers Electrical Company, Ltd. Dr. W. H. Darlington has become chief engineer, gas turbine engineering department.

THE STANTON IRONWORKS COMPANY, Ltd., announces the appointment of Sir Frederick Scopes as chairman and general managing director. He succeeds Mr. A. G. Stewart, who finds it necessary to retire from the board. Mr. N. C. Macdiarmid succeeds Sir Frederick as managing director.

THE NORTHERN ALUMINIUM COMPANY, Ltd., has announced that Mr. E. D. Robinson has been appointed area sales manager in charge of the Manchester office in succession to Mr. D. A. Corbett-Thomson, and Mr. M. Bridgewater, manager of the sales division, Banbury, in succession to Mr. E. D. Iliff.

HADFIELDS, Ltd., has announced the appointment of Mr. T. H. Arnold as research controller and local director. He has also been appointed a director of Hadfields Steels, Ltd., and Hadfields Forgings, Ltd. Dr. L. G. Finch has been appointed deputy research controller. Mr. D. R. Eastwood, M.I.Mech.E., M.I.E.E., deputy chief engineer, has been appointed a local director, and a director of Hadfields Foundry and Engineering Company, Ltd. Dr. J. R. Rait will leave the company at the end of September to take up a new appointment. Mr. S. Leetch, works controller, has announced his retirement from industrial activities as from the end of September.

Business Announcements

KEITH BLACKMAN, Ltd., has announced the inauguration of its new acoustic laboratory at its head office and works at Tottenham, London, N.17.

RHODEN PARTNERS, Ltd., states that it has moved from North Row, London, W.1, to larger premises at 29, Park Crescent, London, W.1 (telephone Langham 7488).

MR. ERIC E. JONES, group commercial director of The Solartron Electronic Group, Ltd., and vice-president of Solartron Incorporated, of Los Angeles, is visiting the U.S.A.

MATERIALS HANDLING EQUIPMENT (GREAT BRITAIN), Ltd., states that it has moved to larger premises at 40a, Dover Street, Piccadilly, London, W.1 (telephone Grosvenor 2934).

G. AND J. WEIR, Ltd., has announced the resignation of Mr. John Young from the board of directors. Mr. Young's services will continue to be available to the company as a consultant.

THE ELECTRICAL ASSOCIATION FOR WOMEN has announced that it has formed a new branch in Somerset. The chairman of the new Bridgwater and District Branch is Mrs. M. Bridges.

SHEPPARD AND SONS, Ltd., Bridgend, Glamorgan, has opened a London sales office at 153, George Street, W.1 (telephone, Paddington 4239). Mr. C. O. Forestier-Walker is the London manager.

THE EXPANDED METAL COMPANY, Ltd., Burwood House, Caxton Street, London, S.W.1, states that it has reorganised its sales force into four separate divisions, building, industrial, stockists and export.

BTR INDUSTRIES, Ltd., states that it has opened a branch office and warehouse at Marshall House, Marshall Street, Birmingham, 1 (telephone, Midland 4602). The new office will be managed by Mr. D. H. Turner.

THE BRITISH COMPUTER SOCIETY has announced the formation of a north-western branch. Its first public meeting will be held at 7 p.m., Monday, October 14, in the College of Science and Technology, Sackville Street, Manchester, 1.

RENOLD CHAINS, Ltd., announces that it has opened a new sales branch office and stock depot at 50, Scotswood Road, Newcastle upon Tyne (telephone, Newcastle 24185). Mr. T. N. Johnston has been placed in control of this new branch.

SIR JOHN HOWARD, M.I.C.E., chairman of the Howard group of companies, is making a tour of the Rhodesias to study the group's operations in that territory. Mr. O. T. R. Leishman, M.I.C.E., director and general manager of John Howard and Co., Ltd., is investigating progress made on the Tema Harbour contract by Parkinson Howard, Ltd.

THE BRITISH REINFORCED CONCRETE ENGINEERING COMPANY, Ltd., states that Mr. Patrick Hall, chairman, has left this country to visit its Canadian subsidiary, B.R.C. Weldmesh, Ltd., Vancouver. He will be joined in Vancouver by Mr. Harold Walker, director in charge of the parent company's overseas business, and together they will visit Jamaica and Trinidad.

Miscellanea

HINKLEY POINT NUCLEAR POWER STATION.—In the summary at the head of our article on the Hinkley Point Nuclear Power Station, which appeared on page 415 of our issue for September 20, the net guaranteed electrical output of the two reactors was inadvertently given as 5MW. This should, of course, have been 500MW, as was stated in the article itself.

END OF HET ATOOM EXHIBITION.—The Het Atoom International Atomic Exhibition in Amsterdam closed on September 15, after being visited by 750,000 people. The exhibition dealt in simplified terms with the practical applications of nuclear fission, and it is reported that the main attraction was a detailed model of Calder Hall. It is planned to send the greater part of the exhibition to other European capitals.

LIGHT ELECTRIC HOIST.—A small, portable, electric hoist is announced by Taylor Stoker Company, Ltd., 189–191, Drummond Street, London, N.W.1. The hoist employs a roller link chain for lifting and is said to have a safety factor of 9 : 1. The basic model is made for handling loads up to 6 cwt, but heavier loads (up to 12 cwt) can be dealt with by an alternative design, in which the lifting chain is doubled. The gear is supplied with a pendant controller and an insulated cable. It may be suspended from a travelling trolley in any position, we hear from the maker, and the trolley may be supplied to suit any runway section. The standard lifting height is 10ft, but longer chains can be supplied. A limit switch prevents over-winding and over-lowering. Two-speed operation can be arranged ; in this case the normal speed is used for general purposes and the slow speed for careful handling.

NATURAL GAS PIPELINE.—The Shell Petroleum Company, Ltd., announces that a new pipeline of 20in diameter has been built to link the La Paz oilfield in the Maracaibo district of the State of Zulia to the Cardon oil refinery in the Paraguana, Venezuela. The pipeline, designed to carry natural gas, is 180 miles in length and has a capacity of 100 million cubic feet per day. High pressure gas is already being pumped from the oilfield and will be burnt in the refinery furnaces and so make additional heavy fuel oil available for export.

LLOYD'S WRECK RETURNS.—Lloyd's Register of Shipping has issued its returns of ships totally lost and broken up during 1956. The world total of steamships and motorships totally lost consequent upon casualty amounted to 163 ships of 248,535 tons gross, of which twenty-four ships of 32,720 tons belonged to Great Britain and Northern Ireland and fourteen ships of 3174 tons to the Commonwealth countries. The corresponding figures for ships broken up in 1956 are, respectively, 378 ships of 528,322 tons gross, 182 ships of 194,444 tons and twenty-two ships of 26,927 tons.

THICKNESS GAUGE FILM.—A preview was given on Thursday, September 19, of a 16mm sound film that has just been completed for the Baldwin Instrument Company, Ltd. The film deals with the company's "Atomat" thickness gauge. A spoken commentary accompanies scenes shot in the works of Venesta Ltd. (aluminium foil), Wiggins Teape (1919), Ltd. (paper), Albert E. Reed and Co., Ltd. (board), and London Abrasives, Ltd. (abrasive papers). The film is called "Nucleonic Measurement" and lasts fifteen minutes. Prints are available from the Baldwin Instrument Company, Ltd., Dartford, Kent.

MR. J. K. SIMPSON.—We record with regret the death, after a long illness, of Mr. J. K. Simpson, the chief engineer and executive director of the Lockheed Hydraulic Brake Company, Ltd., and Associated Companies. Mr. Simpson, who was forty-six, served his apprenticeship with Sir W. G. Armstrong Whitworth, Ltd., at Coventry, before joining the research and development department of the Lockheed Hydraulic Brake Company. In 1937 he transferred to the aircraft division and nine years later became development and experimental engineer to the group. He became chief engineer in 1954 and was appointed executive director in January, 1956.

HEAVY MEDIA SEPARATION EQUIPMENT.—A licence for the manufacture of the "OCC" equipment for heavy media separation in the coal, mineral and other industries has been acquired by Pegson, Ltd., Coalville, from the Ore and Chemical Corporation of the United States. In the vessel used in this process the feed is introduced at the surface level of the media and the plant material is discharged over a weir at one end. Material which sinks through the media to the bottom of the vessel is removed by an oscillating rake and discharged at alternate ends of the vessel, to fall into a launder chamber leading to a discharge chute. Floating barrier screens prevent the float material getting to the discharge points for the sink material. Five sizes of the equipment are to be made by Pegson, Ltd., with capacities up to 400 tons per hour feed.

INSTITUTION OF CIVIL ENGINEERS' PUBLICATIONS.—Starting with this year's session, the Institution of Civil Engineers is publishing a monthly volume of *Proceedings*, into which is incorporated a section entitled "News," the successor to the magazine *Chartered Civil Engineer*, which ceased publication in July. The change, which is part of a programme of rationalisation, also marks the end of the distribution of advance copies of papers before meetings. Papers will now be printed in the *Proceedings* a month ahead ; about six months later the discussion of the paper, both oral and written, will appear. A section entitled "Minutes of Proceedings" will be at the end of the volume reporting the business of each meeting, and obituaries. Separate copies of papers can be provided about a week prior to the meeting concerned at a cost of 2s. post free to members and 4s. to non-members.

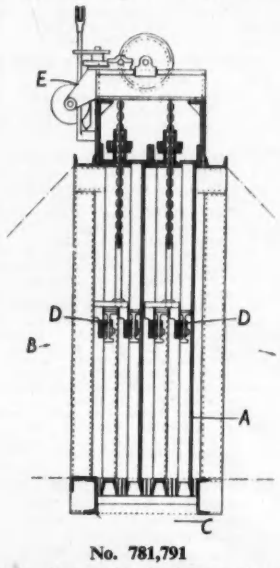
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

STEAM GENERATORS

781,791. February 23, 1955.—Steam Generating Plants in which Entrained Sodium Salts are Recovered from Boiler Flue Gas, E. Green and Son, Ltd., Economiser Works, Wakefield, Yorkshire. (*Inventor: Cyril Wright Parris.*)

The invention relates to steam generating plants of the kind installed in wood pulp mills comprising a boiler fired with black liquor from the digesters, and having arrangements for the recovery from the boiler flue gases of the sodium salts entrained after the combustibles in the liquor have been consumed in the boiler furnace. In the example shown in the drawing, the grit catcher, which is not intended to trap more than a part of the fine dust, employs vertical hollow members *A* preferably of cast iron and curved in cross-section with their concave surfaces presented to the gas stream which flows in the direction indicated by the arrow *B*, the members *A* being arranged in rows in staggered relation to the gases. The larger



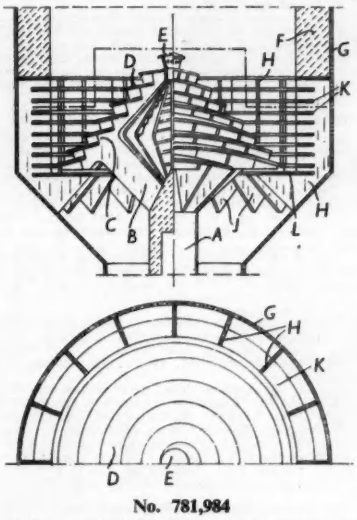
No. 781,791

grit particles then strike the inner surfaces of the vertical members and fall into a hopper *C* below the apparatus, through holes in the bottom of the vertical members. Such part of the gases as may flow into the hopper through the clearing holes is permitted to return to the main gas stream through an exit arranged above the hopper after the main apparatus. The hollow members *A* have mechanically operated scraping apparatus *D* both inside and out, so that particles of molten salts adhering to the surfaces can be removed. For this purpose, it is convenient to make the hollow members *A* of predominantly circular form, and the scraping apparatus *D* and driving gear *E* may well follow the well-known principles established for the scraper gear used for vertical tube economisers.—*August* 28, 1957.

LIME-BURNING

781,984. September 27, 1954.—A Process for Burning Cement and Lime in Shaft Kilns, Portland-Zementwerke Heidelberg Aktiengesellschaft, Riedstrasse 4, Heidelberg, Germany.

The invention relates to a process for burning cement, lime, &c., in shaft kilns, and in particular to a method of preventing the formation of a compact, sintered clinker during such burning. As shown in the drawing, there is employed a rotary grate which has a shaft *A* which can be driven from a main shaft. The shaft *A* carries radially arranged angular ribs *B*, the upward converging arms of which have a stepped exterior profile. Each of the stepped portions *C* is so arranged that it is possible for a spirally extending plate *D* to be placed on it, the plate terminating in a cap *E*. There is thus provided a spirally stepped cone, the exterior walls of which are formed by the spiral plate *D*. The grate spiral may also be constructed with two or more starts. The lining *F* of the kiln body *G* is replaced in the region of the grate cone by a number of radial ribs or fins *H* which extend beneath the grate spiral by means of projecting tongues *J*. Annular discs *K* disposed one above the other are let into the radial ribs, but these discs do not extend as far as the kiln body. The lowermost annular disc *L* is extended beneath the grate spiral. The downwardly advancing burnt material is ground by the milling effect of the revolving grate spiral, and is then displaced outwards over the discs *K*, while some material is able to pass through the grate spiral *D* and into the cavity of the grate, from which it is then able to drop down between the angular ribs *B*. The construction may, however, also be such that all the material is discharged outwardly only through the openings between the ribs *H* and the discs *K* or the grate spiral. It is merely necessary that the grate



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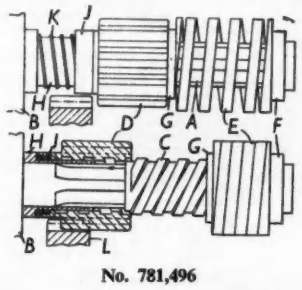
spiral ribs and discs should overlap in such a manner that the comminuted clinker cannot slip through of its own accord, but can only be discharged by the movement of the grate. The discharge quantity may be determined by the formation of the grate spiral as regards slope and pitch, and also by the speed of revolution of the grate. An adequate supply of air is admitted through the openings between the ribs *B* and the spiral plate *D* as well as between the ribs *H* and the annular discs *K*, thus distributing the air all over the cross section of the kiln. Several modified designs are also shown in the specification.—*August* 28, 1957.

INTERNAL COMBUSTION ENGINES

781,496. December 23, 1954, Engine Starting Apparatus, Joseph Lucas (Industries), Ltd., Great King Street, Birmingham, 19. (*Inventor: Charles Edwin Robinson.*)

The invention relates to apparatus for starting an internal combustion engine, the object being to provide a construction whereby in the event of an excessive torque being exerted on the pinion it is automatically rendered inoperative. Referring to the drawing, the apparatus shown is of conventional



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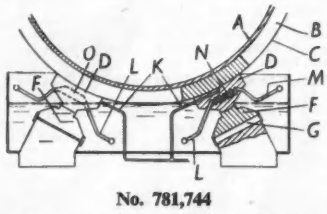
construction. It comprises a splined driving spindle *A* driven by an electric motor *B* or other source, an externally screw threaded and internally splined sleeve *C* slidably mounted on the spindle, and an internally threaded pinion *D* mounted on the sleeve. A portion of the spindle is surrounded by a control spring *E* which at its ends abuts against a collar *F* on the spindle and a washer *G* which abuts against one end of the pinion. The end of the spindle adjacent the motor is embraced by a fixed boss *H* on which the pinion can ride when moved to its operative position. On the boss is mounted an axially slidable collar *J* which is moved to the position shown in the upper view by a spring *K*. According to the invention, the end of the sleeve *C* remote from the spring *E* is shaped to provide a plain portion on which the adjacent end of the pinion can ride idly when the pinion is moved to the position shown in the lower view. Two methods of forming the required plain end on the sleeve are illustrated in the specification. The action is as follows. On setting the spindle *A* in motion the pinion *D* is caused by its inertia, or by an imposed restraint, to slide along the thread of the sleeve into engagement with a toothed wheel *L* on the engine in the usual manner, any shock set up in this movement being absorbed by the spring *E* associated with the sleeve. But in the event of an abnormal torque being exerted on the pinion, as by excessive resistance in the engine, or by accidental reverse of the engine, the sleeve is caused to move endwise to an abnormal extent against the action of the spring, as shown in the lower view, so allowing it to pass out of engagement with the screwed part of the sleeve and thus obviating injury to the mechanism. On release of the overload, the sleeve is returned by the spring, whereupon the pinion and sleeve re-engage and the pinion is ejected to its initial position in the usual manner after the engine has been properly started.—*August* 21, 1957.

BEARINGS AND SUPPORTS

781,744. November 3, 1955.—Supports for Large Rotary Drums, F. L. Smidth and Co. A/S, 33, Vestergade, Copenhagen K, Denmark. (*Inventor: Otto Peder Frankert.*)

According to the invention side self-adjusting shoes supporting a large rotary drum have one or more internal passages for a cooling liquid, preferably water, with flexible pipes for the supply and discharge of the cooling liquid from the passages. In the drawing, a tube mill is shown, with a cylindrical wall *A*



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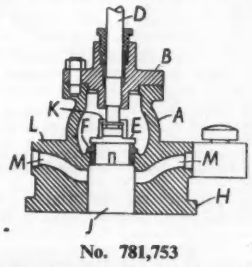
surrounded by a ring B which externally presents a sliding surface *C*. The mill is carried by two slide shoes *D*, each having a part-cylindrical sliding surface of bearing metal. The slide shoes are self-adjusting each resting on a bearing section *F* which is carried through a steel cylinder *G* on pedestals. Such shoes can move slightly and adjust themselves to any slight irregularity of the ring. The sliding surfaces are lubricated by oil picked up from an oil bath, and when the mill is started oil is pumped into the space between the surfaces through pipes *K*. In order to maintain the viscosity of the oil despite any rise in temperature, the shoes are cooled by water forced through pipes *L* and leaving through pipes *M*. The right-hand shoe has a spiral pipe *N* embedded in and connected to the pipes *L* and *M*, and the left-hand shoe is made with an internal space *O* to which the shoes are connected. It is understood that in practice the shoes should have identical internal passages, and that the passages shown are for illustration purposes only. The pipes *K*, *L* and *M* must be flexible to allow of the movement of the shoes.—*August* 21, 1957.

FIRE PROTECTION

781,753. February 9, 1953.—Fire Hydrants, H. Lindley, Ltd., Empire House, 10, Piccadilly, Bradford. (*Inventor: Robert Lindley.*)

The invention relates to fire hydrants and provides a simple and effective means whereby water may be taken from the main or the pressure of the main read without adjustment of the hydrant. As shown in the drawing, a fire hydrant constructed in accordance with the invention comprises a body member *A* having mounted on its upper end a stuffing box *B*. Extending through the stuffing box is a spindle *D* on one end of which is a valve *E*, which when the hydrant is in the closed position rests on a detachable



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seat *F* in the body. The lower half of the body has formed on it a flange *H* in which is the valve inlet *J*. Cast on each side of the body and at right angles to the outlet port *K*, are bosses *L* extending through which are passages *M* tapped to receive a valve, plug or pressure gauge. Thus, when a hydrant is utilised in a position where one of its sides is against a wall, the boss adjacent the wall may be plugged whilst the second boss has a valve mounted on it and a further supply of water can be taken off, irrespective of the hydrant control. A pressure gauge may, if required, be mounted in the boss.—*August* 28, 1957.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Tues., Oct. 1.—OXFORD, READING AND DISTRICTS BRANCH: Agricultural Hall, 121, Oxford Road, Reading, "Space Flight," L. R. Sheppard, 7.15 p.m. ★S.E. LONDON BRANCH: Eltham Green School, Queenscroft Road, Eltham, London, S.E.9, "The Work of the National Inspection Council," E. J. Sutton, 7.15 p.m. ★W. LONDON BRANCH: Windsor Castle Hotel, 134, King Street, Hammersmith, London, W.6, "M.V. Switchgear—Design and Application," E. Jacks, 7.30 p.m.

Wed., Oct. 2.—GLASGOW BRANCH: Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, Branch Lecturettes, 8 p.m. ★MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, "Railway Electrification," J. K. Lord, 7 p.m. ★N. LONDON BRANCH: Queens Head, 677, Green Lanes, Harringay, London, N.4, "Electric Lifts and Equipment," W. T. Wagon, 7.45 p.m. ★PRESTON BRANCH: R.A.F.A. Club, East View, Preston "Miniature Circuit Breakers," H. W. Wolff, 7.30 p.m.

Thurs., Oct. 3.—SOUTHAMPTON BRANCH: Polygon Hotel, Southampton, "Some Problems in Sound Production," F. H. Brittain, 8 p.m.

Fri., Oct. 4.—BRISTOL AND WEST OF ENGLAND BRANCH: Royal York Hotel, Bath, Film Show, 8 p.m. ★LIVERPOOL AND DISTRICT BRANCH: Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, "Earthing and its Problems," P. W. Cave, 7.30 p.m.

Sat., Oct. 5.—OXFORD, READING AND DISTRICTS BRANCH: Hampden Buildings, Temple Square, Aylesbury, "The Thirteenth Edition of the I.E.E. Wire Regulations," J. J. Looker, 7 p.m.

ILLUMINATING ENGINEERING SOCIETY

To-day, Sept. 27.—BIRMINGHAM CENTRE: Regent House, St. Phillip's Place, Colmore Row, Birmingham, Chairman's Address, G. E. Kemp, 6 p.m.

Mon., Sept. 30.—LEEDS CENTRE: Griffin Hotel, Boar Lane, Leeds, Annual Dinner and Chairman's Induction, 7.30 p.m.

Tues., Oct. 1.—STOKE-ON-TRENT GROUP: North Stafford Hotel, Stoke-on-Trent, "The Polar Aurorae," G. E. Kemp, 6 p.m.

Wed., Oct. 2.—SWANSEA GROUP: Demonstration Theatre, South Wales Electricity Board, The Kingsway, Swansea, Chairman's Address, D. B. Francis, 6.30 p.m. ★NEWCASTLE UPON TYNE CENTRE: Lecture Theatre, Grey Hall, Department of Electrical Engineering, King's College, College Road, Newcastle upon Tyne, Annual General Meeting and Chairman's Address, R. J. Fothergill, 6.15 p.m. ★EDINBURGH CENTRE: Y.M.C.A. Social Room, 14, South Saint Andrew Street, Edinburgh, "Lighting in the Home," D. P. Bliss and H. Hellier, 6.15 p.m.

Thurs., Oct. 3.—GLASGOW CENTRE: Lighting Service Bureau of Scotland, 29, St. Vincent Place, Glasgow, "Lighting in the Home," D. P. Bliss and H. Hellier, 6.30 p.m.

Tues., Oct. 8.—LONDON MEETING: Royal Institution, Albemarle Street, London, W.1, Presidential Address, "Designing for Harmony," E. B. Sawyer, 6 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Sept. 27.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "Some Principles of Radiant Heating," P. A. Coles, 7.30 p.m.

Mon., Sept. 30.—W. AND E. YORKSHIRE BRANCH: Leeds University, "The Safe Use of Electricity," J. J. Emerson, 7.30 p.m.

Tues., Oct. 1.—GENERAL MEETING: Royal Society of Arts, John Adam Street, Adelphi, Strand, London, W.C.2, "Reactor Plant Engineering," R. F. Jackson, 7 p.m. ★E. MIDLANDS BRANCH: County Hotel, Theatre Square, Nottingham, "The Heat Pump: Some Aspects of its Application," J. A. Sumner, 7 p.m. ★EDINBURGH BRANCH: 25, Charlotte Square, Edinburgh, "Practical Plant Engineering in the Chemical Industry," C. W. Winstock, 7 p.m. ★PETERBOROUGH BRANCH: White Lion Hotel, Church Street, Peterborough, "Hydro-Electric Power Development," G. C. Cummings, 7.30 p.m.

Wed., Oct. 2.—LEICESTER BRANCH: Bell Hotel, Leicester, "Factory Flooring," F. C. Harper, 7 p.m. ★SOUTHERN BRANCH: "Royal Beach Hotel, Portsmouth, "The Engineer and the Clean Air Act," E. C. Rogers, 7.30 p.m.

Tues., Oct. 8.—MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, "Chain Grate Stokers," C. H. G. Hayward, 7.15 p.m.

Thurs., Oct. 10.—GLASGOW BRANCH: Scottish Building Centre, 425–427, Sauchiehall Street, Glasgow, "The Measurement and Prevention of Smoke from Industrial Boilers," T. F. Hurley, 7.15 p.m. ★MANCHESTER BRANCH AND MERSEYSIDE AND N. WALES BRANCH: Joint Meeting, Aboard Clubship "Landfall," "What Purpose does Incorporated Plant Engineers Serve?" 7.15 p.m. ★N.E. BRANCH: Roadway House, Oxford Street, Newcastle upon Tyne, "The Manufacture of Tubes," H. B. Elliot, 7 p.m.

Mon., Oct. 14.—DUNDEE BRANCH: Mathers Hotel, Dundee, "Boiler Feed Systems and Auxiliaries," J. R. Cairns, 7.30 p.m.

Wed., Oct. 16.—KENT BRANCH: Kings Head Hotel, High Street, Rochester, "The Generation of Power from Atomic Energy," H. R. M. Hyder, 7 p.m.

Thurs., Oct. 17.—BLACKBURN BRANCH: Golden Lion Hotel, Blackburn, "Man Management," A. Roberts, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Wed., Oct. 2.—SOUTHAMPTON SECTION: Technical College, St. Mary's Street, Southampton, "Thoughts on the Development of the CO_2 Process," A. Talbot, 7.30 p.m.

Tues., Oct. 8.—SLOUGH SECTION: Lecture Theatre, High Duty Alloys, Ltd., Slough, "The Know-How of the CO_2 Process," A Brains Trust, 7.30 p.m.

Thurs., Oct. 10.—BEDS AND HERTS SECTION: K. and L. Steelfounders and Engineers, Ltd., Letchworth, Presidential Evening, G. Smith, 7.30 p.m.

INSTITUTE OF FUEL

Wed., Oct. 9.—Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, Symposium on "Flames and Industry," 10 a.m.

INSTITUTE OF MARINE ENGINEERS

Tues., Oct. 1.—Memorial Building, 76, Mark Lane, London, E.C.3, Presidential Address, "Lloyd's Register of Shipping and the Marine Engineer," Sir Ronald Garrett, 5.30 p.m.

Tues., Oct. 8.—Memorial Building, 76, Mark Lane, London, E.C.3, "Recent Developments in British Naval Main Propulsion Steam Turbines," F. J. Cowlin and A. F. Veitch, 5.30 p.m.

Mon., Oct. 14.—STUDENT MEETING: Memorial Building, 76, Mark Lane, London, E.C.3, Films, "Super Tanker" and "Foothold on Antarctica," 6.30 p.m.

INSTITUTE OF PETROLEUM

Wed., Oct. 2.—26, Portland Place, London, W.1, "Modern Trends in Petroleum Analysis," H. Powell and W. H. Thomas, and "New Trends in the Instrumentation of Refinery Processes," S. W. J. Wallis and D. S. Townend, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Wed., Oct. 2.—E. MIDLANDS CENTRE: Mechanics' Institute, Nottingham, "The Free Piston Gasifier with special reference to Vehicle Applications," 7.30 p.m.

Thurs., Oct. 3.—Royal Society of Arts, John Adam Street, Strand, London, W.C.2, Twelfth Annual General Meeting, 6.30 p.m. ★METROPOLITAN AREA: Royal Society of Arts, John Adam Street, London, W.C.2, Annual General Meeting, followed by Films, 6.30 p.m. ★N. REGIONAL CENTRE: Victoria and Station Hotel, Preston, "The Ability to Stop," H. Clements, 7.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Oct. 1.—Great George Street, Westminster, London, S.W.1, "The Design and Construction of the Hindiya Bridge," J. F. C. Swansbourne, 5.30 p.m.

Tues., Oct. 8.—Great George Street, Westminster, London, S.W.1, "Investigation of Rainfall, Runoff and Yield on the Alwen-Brenig Catchments," W. K. Lewis, 5.30 p.m.

Tues., Oct. 15.—Great George Street, Westminster, London, S.W.1, "An Investigation into a Proposal to Dispose of Power Station Ash by Discharging it into the Sea at Low Water," F. L. Harwood and K. C. Wilson, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Tues., Oct. 1.—E. MIDLANDS CENTRE: Loughborough College, Informal Conversazione and Reunion, 6.30 p.m. ★N. MIDLAND CENTRE: Central Electricity Authority, Yorkshire Division, 1, Whitehall Road, Leeds, Chairman's Address, A. J. Coveney, 6.30 p.m. ★N.W. CENTRE: Engineers' Club, 17, Albert Square, Manchester, Chairman's Address, F. R. Perry, 6.30 p.m. ★S.E. SCOTLAND SUB-CENTRE: Carlton Hotel, North Bridge, Edinburgh, Chairman's Address, E. O. Taylor, 7 p.m.

Wed., Oct. 2.—S.W. SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Chairman's Address, E. O. Taylor, 7 p.m. ★S. CENTRE: Central Electricity Authority, Portsmouth, Chairman's Address, L. G. A. Sims, 6.30 p.m.

Thurs., Oct. 3.—ORDINARY MEETING: Savoy Place, London, W.C.2, Inaugural Address as President, T. E. Goldup, 5.30 p.m.

Fri., Oct. 4.—N. SCOTLAND SUB-CENTRE: Robert Gordon's Technical College, Aberdeen, Chairman's Address, E. O. Taylor, 7.30 p.m.

Mon., Oct. 7.—E. ANGLIAN SUB-CENTRE: Assembly House, Norwich, Chairman's Address, "Education for Engineers," G. E. Middleton, 7.30 p.m. ★MERSEY AND N. WALES CENTRE: Royal Institute, Colquitt Street, Liverpool, Chairman's Address, "Development of Electrical Services in a Soap and Chemical Factory," T. Makin, 6.30 p.m. ★S. MIDLAND CENTRE: Grand Hotel, Birmingham, Chairman's Address, L. I. Tolley, and Annual General Meeting, and Conversazione, 6 p.m.

Tues., Oct. 8.—MEASUREMENT AND CONTROL SECTION: Savoy Place, London, W.C.2, Chairman's Address, "Meters and Meter Engineers," H. S. Petch, 5.30 p.m. ★E. MIDLAND CENTRE: Loughborough College, Chairman's Address, J. D. Pierce, and Annual General Meeting, 6.30 p.m. ★CAMBRIDGE RADIO AND TELECOMMUNICATION GROUP: Cambridgeshire Technical College, Chairman's Address, N. C. Rolfe, 6.30 p.m. ★N.W. UTILIZATION GROUP: Engineers' Club, 17, Albert Square, Manchester, "Electrical Floor Warming," J. W. Moule and W. M. Stevenson, 6.15 p.m. ★N. IRELAND CENTRE: David Keir Building, Queen's University, Belfast, Chairman's Address, "Brief Review of the Progress of the Electricity Board for Northern Ireland," C. M. Stoupe, 6.30 p.m.

Wed., Oct. 9.—N.W. RADIO AND TELECOMMUNICATION GROUP: Engineers' Club, 17, Albert Square, Manchester, Chairman's Address, K. J. Butler, 6.45 p.m. ★N. LANCASHIRE SUB-CENTRE: N.W. Electricity Board Demonstration Theatre, 19, Friargate, Preston, Chairman's Address, H. G. Cope, 7.15 p.m. ★RUGBY SUB-CENTRE: Rugby College of Technology and Arts, Chairman's Address, W. J. Carfrae, 6.30 p.m. ★OXFORD BRANCH: S. Electricity Board, 37, George Street, Oxford, "Visit of Electrical Delegation to Russia," D. P. Sayers, 7 p.m.

Thurs., Oct. 10.—UTILIZATION SECTION: Savoy Place, London, W.C.2, Chairman's Address, "Joints and Hinges," J. Vaughan Harries, 5.30 p.m. ★N. MIDLAND CENTRE: Yorkshire Electricity Board, Ferensway, Hull, "A New Meter for the kVA Demand Charge," P. Baxter, 6.30 p.m. ★W. WALES (SWANSEA) SUB-CENTRE: S. Wales Electricity Board Showrooms, The Kingsway, Swansea, Chairman's Address, I. G. Evans, 6 p.m.

Mon., Oct. 14.—INFORMAL MEETING: Savoy Place, London, W.C.2, Discussion on "The Social Consequences of Automation," to be opened by the President, 5.30 p.m. ★N.E. CENTRE: Neville Hall, Newcastle upon Tyne, Chairman's Address, T. W. Wilcox, 6.15 p.m. ★N. STAFFORDSHIRE SUB-CENTRE: Jubilee Hall, Stoke-on-Trent, Chairman's Address, H. A. P. Caddell, 7 p.m. ★WESTERN CENTRE: South Wales Institute of Engineers, Cardiff, Chairman's Address, J. F. Wright, 6 p.m.

Tues., Oct. 15.—N. MIDLAND CENTRE: Central Electricity Authority, Yorkshire Division, 1, Whitehall Road, Leeds, "Electrical Equipment for Rectifier Locomotives," H. B. Calverley, E. A. K. Jarvis and E. Williams, 6.30 p.m. ★N.W. SUPPLY GROUP: Engineers' Club, Albert Square, Manchester, "Experiences in the U.S.S.R.," H. West, 6.15 p.m. ★S.E. SCOTLAND SUB-CENTRE: Carlton Hotel, North Bridge, Edinburgh, Sub-Centre Chairman's Address, J. Mendelson, 7 p.m. ★S.W. SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Sub-Centre Chairman's Address, A. J. Small, 7 p.m.

Wed., Oct. 16.—RADIO AND TELECOMMUNICATION SECTION: Savoy Place, London, W.C.2, Chairman's Address, "Some Radio Aids for High-Speed Aircraft," J. S. McPetrie, 5.30 p.m. ★SHEFFIELD SUB-CENTRE: Grand Hotel, Sheffield, Chairman's Address, O. I. Butler, 6.30 p.m. ★SOUTHERN CENTRE: Brighton Technical College, "Electrical Floor Warming," J. W. Moule and W. M. Stevenson, 6.30 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Mon., Oct. 14.—N.E. BRANCH: Northern Architectural Association Hall, 6, Higham Place, Newcastle upon Tyne, "Building Structures," G. Gladstone, 7.15 p.m.

INSTITUTION OF ENGINEERS IN CHARGE

Wed., Oct. 9.—Caxton Hall, Caxton Street, Westminster, London, S.W.1, Forty-Fourth Annual General Meeting, 6.30 p.m.

Fri., Oct. 25.—Caxton Hall, Caxton Street, Westminster, London, S.W.1, Presidential Address, Sir Harold Roxbee Cox, 6.30 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Tues., Oct. 1.—E. ANGLIA BRANCH: Assembly House, Norwich "Ordnance Survey," E. P. J. Williams, 6.30 p.m.

Thurs., Oct. 3.—YORKSHIRE AND LINCOLNSHIRE BRANCH: Technical College, Lincoln, "Control in the Manufacture and Laying of Bituminous Materials," H. G. Barnes, 7 p.m.

Fri., Oct. 4.—LONDON BRANCH: Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "Construction of Soil Cement Roads and Road Bases in Holland," F. A. Van der Sluis, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Tues., Oct. 1.—COVENTRY A.D. CENTRE: Leofric Hotel, Coventry, "The Suspension of Internal Combustion Engines in Vehicles," M. Horovitz, 7.30 p.m.

Wed., Oct. 2.—SOUTHERN BRANCH: Visit to the Atomic Energy Research Establishment, Harwell, 2.30 p.m., followed by "Patenting an Invention," C. Lea, 7 p.m.

Thurs., Oct. 3.—N.W. BRANCH: Engineers' Club, 17, Albert Square, Manchester, "Principles and Applications of Hydrodynamic-type Gas Bearings," G. W. K. Ford, D. M. Harris and D. Pantall, 6.45 p.m. ★E. MIDLANDS GRADUATE SECTION: Grand Hotel, Leicester, "Some Highlights in the History of Mechanical Engineering," E. G. Sterland, 7.15 p.m. ★YORKSHIRE GRADUATE SECTION: Grand Hotel, Sheffield, Ladies' Invitation Evening, "Mechanical Engineering in the Kitchen," 7.30 p.m.

Fri., Oct. 4.—BARROW-IN-FURNESS PANEL: Central College for Further Education, Lecture Theatre, Abbey Road, Barrow-in-Furness, "The Steam Catapult," C. C. Mitchell and Q. H. Paterson, 7.30 p.m.

Mon., Oct. 7.—N.E. BRANCH: Neville Hall, Westgate Road, Newcastle upon Tyne, Chairman's Address, 6 p.m.

Tues., Oct. 8.—AUTOMOBILE DIVISION: 1, Birdcage Walk, Westminster, London, S.W.1, Annual General Meeting, followed by the Chairman's Address, 6 p.m. ★EASTERN BRANCH: Red Lion Hotel, Colchester, Chairman's Address, "Heat and Power for Industry: Some Technical Considerations of the Effect of Current Trends in the Availability of Fuel," G. W. Bone, 7.30 p.m. ★RUGBY PANEL: Lawrence Sheriff School, Rugby, "Motive Power on Sea and Land," T. A. Crowe, 6.30 p.m. ★N.E. BRANCH: Cleveland Institute, Corporation Road, Middlesbrough, Chairman's Address, 6.15 p.m. ★S. WALES BRANCH: S. Wales Electricity Board's Lecture Theatre, Kingsway, Swansea, "Applications of Radioisotopes to Engineering," D. B. Smith, 6 p.m.

INSTITUTION OF MINING AND METALLURGY

Thurs., Oct. 17.—GENERAL MEETING: Geological Society, Burlington House, Piccadilly, London, W.1, "Control of Air Pressure as an Aid to Fight Mine Fires," J. M. Caw, and "The Production of Zinc in a Blast Furnace," S. W. K. Morgan, 5 p.m.

INSTITUTION OF NAVAL ARCHITECTS

Thurs., Oct. 10.—Weir Lecture Hall, 10, Upper Belgrave Street, London, S.W.1, "Some Problems of Yacht Measurement," D. Phillips-Birt, 4.45 p.m.

INSTITUTION OF NAVAL ARCHITECTS AND THE INSTITUTE OF MARINE ENGINEERS

Tues., Oct. 1.—SOUTHERN JOINT BRANCH: Portsmouth College of Technology, "Some Applications of Electronics to Ship Tank Investigations," S. G. Lankester, 7.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Wed., Oct. 2.—INFORMAL MEETING: Conference Room, Fourth Floor, Waterloo Bridge House, London, S.E.1, Vice-Chairman's Address, "Accommodation for Work and Welfare," 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Sept. 27.—LEICESTER SECTION: Grand Hotel, Leicester, "Work Measurement and Its Uses for Management," W. Hewett, 7 p.m.

Wed., Oct. 2.—N. MIDLANDS REGION: Victoria Station Hotel, Nottingham, "Principles and Applications of Pneumatics in Production," F. Kay, 7 p.m. ★N.W. REGION: The Harris College of Further Education, Corporation Street, Preston, "The Production of Nuclear Fuels for the Atomic Power Programme," J. E. Littlechild, 7.30 p.m. ★S.E. REGION: Mid-Essex Technical College and School of Art, Chelmsford, "Pride in Workmanship," Sir Gordon Russell, 7.30 p.m.

Thurs., Oct. 3.—MIDLANDS REGION: Craven Arms Hotel, High Street, Coventry, "Dynamic Balancing—A Growing Production Problem," J. Tye, 7.15 p.m. ★MIDLANDS REGION: College of Further Education, Redditch, "Accurate Measurement in Engineering Production," J. Loxham, 7.30 p.m. ★SOUTHERN REGION: Great Western Hotel, Reading, "Some Aspects of Automation," A. L. Stuchbery, 7.30 p.m.

Fri., Oct. 4.—Dorchester Hotel, Park Lane, London, W.1, Annual Dinner. ★EASTERN REGION: Britannia Works Canteen, Davey, Paxman and Co., Ltd., Colchester, "Automation—Development of Transfer Equipment," A. J. Sephton 7.30 p.m.

INSTITUTION OF WORKS MANAGERS

Tues., Oct. 1.—MERSEYSIDE BRANCH: Adelphi Hotel, Mersey, Annual General Meeting and Dinner, 6.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

Wed., Oct. 2.—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, Annual General Meeting, 7 p.m.

Fri., Oct. 4.—LONDON SECTION: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Opening Meeting of 1957–58 Session, 7 p.m.

LIVERPOOL METALLURGICAL SOCIETY

Thurs., Oct. 10.—Liverpool Engineering Society, The Temple, Dale Street, Liverpool, Presidential Address, J. S. W. Graham, 7 p.m.

MANCHESTER GEOLOGICAL AND MINING SOCIETY

Thurs., Oct. 10.—Mining and Technical College, Wigan, Annual General Meeting, 3.30 p.m.

PLASTICS INSTITUTE

Thurs., Oct. 3.—SOUTHERN SECTION: Chemistry Department, University of Southampton, "Urea and Melamine Resins in the Wet Strength Paper Field," G. F. Glover, 7.30 p.m.

Fri., Oct. 4.—FIFTH EDUCATION CONFERENCE: Borough Polytechnic, Borough Road, London, S.E.1, "Challenge of Plastics to the Arts and Technology," Sir Miles Thomas, 2.30 p.m. ★Science Museum, South Kensington, London, S.W.7, President's Reception and Conversazione, 8 p.m.

ROYAL SOCIETY OF HEALTH

Thurs., Oct. 3.—WEYMOUTH SESSIONAL MEETING: St. John Hall, Westway Road, Weymouth, "Public Health Aspects of Atomic Energy," Katharine Williams, 10.30 a.m.

SOCIETY FOR WATER TREATMENT AND EXAMINATION

Wed. to Fri., Oct. 2 *to* 4.—Palace Hotel, Southend-on-Sea, Autumn Meeting.

Advanced Engineering Courses

Structural Design in Timber. Dr. L. G. BOOTH. BATTERSEA COLLEGE OF TECHNOLOGY, Battersea Park Road, London, S.W.11. Course of ten lectures commencing October 4, Friday evenings from 6.45 to 9. Fee £1.

The Oxidation of Hydrocarbons. Dr. C. F. H. TIPPER. UNIVERSITY OF LIVERPOOL DEPARTMENT OF EXTRA-MURAL STUDIES, TECHNICAL COLLEGE, Borough Road, Birkenhead. Course of ten lectures commencing October 8, Tuesday evenings, from 6.15 to 7.45. Fee £2 2s.

An Introduction to Nuclear Power. NORTHAMPTON COLLEGE OF ADVANCED TECHNOLOGY, St. John Street, London, E.C.1. Course of twenty lectures, forming the first year of a two-year course in nuclear power, commencing October 11, Friday evenings, from 7 to 9. Fee £2.

The Technique of Technical Writing. G. PARR. BOROUGH POLYTECHNIC, Borough Road, London, S.E.1. Course of six lectures, commencing October 11, Fridays, at 2.30 p.m. Fee 10s.